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ITALIAN IRRIGATION

BEING A REPORT ON THE

AGRICULTURAL CANALS OF PIEDMONT AND LOMBARDY

ADDRESSED TO THE HONOURABLE THE COURT OF DIRECTORS
OF THE EAST INDIA COMPANY

BY

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PART I.

PERSONAL NARRATIVE.

THE IRRIGATION SYSTEM

OF

NORTHERN ITALY.

PART I.

PERSONAL NARRATIVE.

CHAPTER I.

PIEDMONT.—PROVINCES OF TURIN, VERCELLI, NOVARA, AND THE LUMELLINA.

THE mission to examine the classic land of irrigation, of which the results are given in the following pages, was undertaken by me, under instructions from the Honourable the Court of Directors of the East India Company. The great works for the improvement of agriculture throughout British India, which of late years have either been completed, or are at this moment in progress of execution, had naturally attracted the attention of the Government of India and its officers to that system of land irrigation which has been so powerful an agent in placing the plains of Northern Italy, even from the earliest historical period, among the richest on the face of the earth. To study this system in its various relations—to

examine the details of its works, so famous in the history of hydraulic engineering—to investigate the principles, and note the practical application of those legislative enactments which, by universal consent, are held to be the most perfect at present in existence—to become familiar with the actual operation of that machinery for the distribution of water to the cultivators, which is considered by most observers to come nearest to the type of theoretical perfection, the history of which will be found hereafter to have an almost romantic interest—and, finally, to observe carefully those sanitary arrangements which the continued experience of ages may have suggested for preserving the public health with the least possible sacrifice of individual interests, were the chief objects prescribed to me in the instructions with which I was favoured. I can scarcely hope that I shall succeed in completing the outline just sketched with all the detail of which the subject is capable. But I may be permitted to say, in a single sentence, that, feeling the truest interest alike in the subject and the object of the work, I have spared no personal exertions in endeavouring to give full effect to the enlightened views of the Government I serve.

However earnest might be the desires of an officer charged with such investigations as are above adverted to, it is very certain that his results must of necessity have been confined within a very limited range, without the assistance of the governments and the administrators of the works generally. It is, therefore, one of my most gratifying duties to record, that such imperfections as doubtless exist in this Report are in no way attributable to any denial of assistance from the local authorities. On the contrary, it is impossible for me to speak too strongly of the kindness I received from all classes with whom my duties brought me into personal relation.

Occasions will present themselves hereafter, in the course of the Personal Narrative, for acknowledging the attentions of individuals; but I cannot refrain from saying here, in general terms, how heartily the Italians of Northern Italy, Lombards, Piedmontese, and Tuscans, of all grades, and in every position, private or official, rendered to me assistance in my work, at once most valuable and most agreeable.

In effecting the objects prescribed to me, there were three principal sources whence information was to be procured: First, from books or official documents treating of Italian irrigation; Second, from oral communication with the engineers or other officers connected with the works; and, Third, from personal examination of the various works themselves. It will, perhaps, show most appropriately the means adopted to render these sources of information as fully available as possible, if I devote this introductory chapter to a rapid sketch of my proceedings during the time I spent in Northern Italy. More than a sketch I do not attempt to give, because the detailed information obtained will naturally arrange itself under those divisions of the subject to which it is specifically appropriate, and to give it here would only lead to wearisome repetition. With this brief explanation, I proceed at once to my personal narrative.

Provided with an official letter of introduction from Viscount Palmerston to the English minister at the court of Sardinia, and with sundry similar documents from private sources, I left London for Paris on the 12th December 1850. Learning in Paris the fact that the French government had on several occasions deputed officers to examine the canals of irrigation in Italy, I naturally felt anxious to procure copies of reports which might have been submitted as the results of such deputa-

tions. I considered myself fortunate in being able to procure, thus early, a copy of the only systematic work which to my knowledge exists on the subject of Italian irrigation—viz., the Practical and Theoretical Treatise by M. Nadault de Buffon.* To this work I have many obligations to acknowledge: it was my constant companion and guide during my subsequent wanderings; its ample details I found to be in general as accurate as they were complete; and though some few errors unquestionably exist in it, their number is small, and their importance slight, as compared with the great mass of valuable and correct information which M. Buffon has collected.

I also obtained, though at a later period, a Report on Irrigation addressed to the Minister of Agriculture and Commerce, by M. de Mauny de Mornay, published in 1844.† This, however, is an imperfect work, being restricted to details of the legislation of irrigation in Northern Italy, and in some of the German kingdoms. The first part of the report, which was to have treated of practical irrigation, has not been published up to the present time, the necessity for it having possibly been obviated by the work of M. de Buffon.

Having remained a few days in Paris, I passed rapidly through France, but with weather so thoroughly dreary and disagreeable as to make enjoyment well-nigh impossible. A fierce *mistral* on the Rhone kept us all prisoners in the little cabin of the steamer, and but for the joyous society of a party of French officers *en route* for Algeria, who received me among them with the frank courtesy of

* "Traité Théorique et Pratique des Irrigations envisagées sous les divers points de vue de la Production Agricole, de la Science Hydraulique, et de la Legislation." 2 vols. Paris: 1844.

† "Rapport à M. le Ministre de l'Agriculture et du Commerce sur la Pratique et la Legislation des Irrigations dans l'Italie Superieure, &c. 2me Partie—Legislation." 1 vol. Paris: 1844.

military brotherhood, the journey must have been a wretched one. Under more genial circumstances there would have been strong temptations to linger a while in the country through which our route now passed, as not only in the valleys of the Rhone and the Durance, but generally throughout Southern France, there is a very large number of canals of irrigation, which it would have been interesting to have visited. As it was, however, delay was not advisable, and I therefore lost no time in starting from Marseilles by the land route for Nice and Genoa. Though new and full of interest to myself, I am well aware that the beautiful route by the Riviera of the Mediterranean is generally too well known to need any description here. It was, however, impossible not to be powerfully affected by the startling and delightful contrast between the bleak wintry aspect of France, and the bright spring-time look of Italy. It seemed as though, in the single day that served to transport us from Marseilles to Nice, an entire season had been comprised, for on the 23d of December we were in mid-winter, and on the 24th in mid-summer. On the former day, scarcely a single green leaf was to be seen; on the latter, we were in the midst of orange groves covered with fruit. Olive trees lined the road, or covered the slopes of the hills; jasmines and other flowers literally filled the air with perfume. I yielded myself freely to the exquisitely enjoyable influences of the beautiful scenes through which I passed; and I must say that my first impressions of Italian scenery realised to their full extent even the brightest anticipations I had indulged in regarding it.

I reached Genoa on the 27th December; and finding that Sir Ralph Abercromby, the English ambassador in Piedmont, was residing in the neighbourhood, I was able at once to deliver the official and private letters I had

for him. To Sir Ralph's unvarying kindness, and to the cordial manner in which he interested himself in securing for me all necessary facilities for the discharge of my duties, I attribute entirely the assistance afforded me in Piedmont; and I must be allowed to express, in the warmest terms, my gratitude for the aid thus afforded to me, the effect of which was not limited to the immediate sphere of his personal influence in the Sardinian States, but followed me into Lombardy and Tuscany.

Provided with letters of introduction to the members of the Sardinian ministry, I left Genoa on the 1st, and reached Turin on the 2d of January 1851. Through the kind assistance of Mr Lettsom, in charge of the British embassy at Turin, I had an early opportunity of delivering the letters with which I was intrusted, to the different ministers at the capital. From all of these (with a solitary exception) * I received the most cordial assistance. The whole of the records of the irrigation department were unreservedly opened for my examination. Every facility for making extracts from, or copies of them, was afforded me; and, on the part of every officer of the government with whom I had occasion to place myself in communication, I found a disposition to anticipate my wishes, and to do even more for me than I required. I could not help being somewhat amused at the way in which these feelings occasionally displayed themselves. It seemed to be a fixed idea with every one from whom I sought information, that they must begin at the very beginning of the subject with me. No assurance

* It leads to a strange association of persons, but it is an unexaggerated fact that, during six months' wandering in Italy, in constant intercourse with people of all grades and all classes, the only instances of personal incivility I met with were from a Sardinian Minister of War and a Tuscan Vetturino. It seems as strange that there should be *one* of the former class, as *only* one of the latter, to complain of; but so it was.

of my own that ten years' constant employment in hydraulic works had made it unnecessary for me to be instructed in the elementary principles of the science—that their canals, in point of volume of water, dimensions of works, or difficulties of original construction and maintenance, were diminutive as compared with those in connection with which my professional life had been spent—were of the slightest avail. It seemed as though they were resolute in believing that out of the Italian school nothing could be learned; and so I had to listen to preliminary disquisitions which were rather more trying to the patience than instructive to the mind. It must in justice, however, be added, that I rarely found the penance without its reward, as, when the foundations had been laid, according to their own ideas of propriety, my kind friends seldom failed to supply me with information really interesting and instructive.

With the means of information Turin presented, I resolved to remain there for some time, and to avail myself of them to the utmost of my power. An additional reason for this determination was, that the season proved so inclement as to make travelling in the interior almost impracticable. I have never experienced a more disagreeable climate than that of Turin during the months of January and February of this year. The cold bleak winds from the Alps, the abundant snow or rain, the miserable fogs, so damp and raw, and even in sunshine the great variations of temperature, constituted a climate so unpleasant that I recall the sufferings of the time I spent under its influence with a shudder, and earnestly hope I may never have to endure the like again.

One of the first duties I had to undertake was to qualify myself for the study of Italian hydraulics in the native tongue; and availing myself of the assistance of an in-

telligent young Lombard refugee, I read with him three hours daily, and found that, before long, I was able to glean from the old hydraulicians those stores of information on which the moderns still depend. The Government of India had, with characteristic liberality, supplied me abundantly with the means of procuring as complete a collection as practicable of the ancient and modern Italian authors on hydraulics, with a view to their being placed in the library attached to the headquarters of the Grand Ganges Canal. I was surprised, and, I must add, much disappointed, by finding the Piedmontese contributions to this branch of scientific literature so very limited and imperfect. With the exception of a few elementary treatises, the experimental researches of the Michellotti, and the memoirs of Professor Bidone, were almost the only works I found. This is the more to be regretted, because, in the records of the irrigation department at Turin, there exist abundant materials for a most perfect account of the system of irrigation in Piedmont as it at present exists; and there are men connected with the office who have all the ability, if they would only form the resolution, to complete, in a satisfactory manner, such an account. That students should find their best, indeed their only complete, guides to the canals of Piedmont in the works of foreign travellers, is a fact so little creditable to native talent and enterprise as to be recorded with regret. The extent to which the existing records may be made available has been illustrated in the solitary instance of the canal of Caluso, one of the oldest and most important in the country, a history of which, in great detail, has been published by M. Michela, the meritorious engineer in charge of the canal office at Turin. The completion of similar accounts of the other canals would leave nothing to be desired.

In the department of legislation, however, the superiority of the Piedmontese must be cordially and unhesitatingly admitted. Not only are the various provisions of the code of Charles Albert, on all points connected with the rights and duties of property in water, the most complete and the most clearly defined with which I have had opportunities of becoming acquainted, but the best treatise on the subject of the legislation of irrigation generally is that of a provincial lawyer of Piedmont, M. Giovanetti of Novara.* Of this work, which is now very rare, I was fortunate enough to procure a copy. It is somewhat difficult to understand, and occasionally a little confused in style, from the circumstance that, though *written* in French, it has evidently been *thought* in Italian; but it is unquestionably a masterly *resumé* of the entire subject; and, with the exceptions above adverted to, it is very clear, distinct, and decisive throughout. I shall have occasion hereafter to refer much to its pages, and I take this opportunity of acknowledging my obligations to its accomplished author.

The admiration of the Piedmontese legislation expressed above applies to the system as embodied in the code, or as expounded by intelligent commentators upon it. It would convey false impressions if I were to leave it to be understood that I view with the same admiration the working of the system in actual practice. Nothing struck me more powerfully and more unpleasantly than the frequently recurring discrepancies between the theory and the practice on many points of the irrigation system. I found the codified provisions not unfrequently much modified in practice, and sometimes violated altogether. In view of such cases I sought an explanation from one of

* "Du Régime des Eaux, par Jacques Giovanetti, Avocat." 1 vol. Lithograph.

the frankest and most intelligent of my Piedmontese friends. "The anomalies you notice are undeniable," was his reply, "and you are likely to see more of them before you leave our country. Perhaps I can best convey to you the secret of their existence by quoting to you a proverb we have, which gives the national idea of their origin, and which declares that 'in Piedmont the laws are in force from *night to morning*'—that is, while men sleep." There is, however, another reason which has probably considerable effect, and is somewhat more creditable, or, at any rate, less discreditable, to the orderly inhabitants of Piedmont than that assigned in the proverb. The Albertine code is of very recent origin. It dates only from 1838. Everybody knows how long old customs linger among an agricultural people. Many of the anomalies observed are doubtless due to old customs, on which the laws opposed to them have not yet had time to act. I am disposed to think it is rather this clinging to old habits, than a want of respect for the law, which puts the people in the light of law-breakers; and there seems to be reason to believe that the tendency of things is to a more complete conformity between theory and practice, though the progress may not be very rapid.

The economical importance of irrigation in Piedmont has naturally induced the government to furnish all practicable facilities for its study. The education of the hydraulic engineer is conducted with care, and no one is allowed to assume the title, or practise the profession, without having graduated regularly at the university of Turin. It may not be without interest to give here a sketch of the manner in which the engineer students are trained for their future work. For the details of this system I am indebted to the intelligent conversation of M. Richelmy, Professor of Hydraulics in the University

of Turin, of whose personal kindness I retain a grateful recollection.

The profession of the civil engineer in Piedmont is divided into three grades, of which the highest is the hydraulic engineer ; the second, the civil architect ; and the third, the surveyor or measurer. For the superior degree, the course of study extends over four years. Before entering the university at all, the engineer student must pass an examination, which embraces arithmetic, elementary geometry, and algebra, to equations of the second degree. In the university course the first year is devoted to the farther study of algebra, of trigonometry, and of analytic geometry ; the second, to the differential and integral calculus and descriptive geometry ; the third to the principles of mechanical philosophy and their applications to machines, with practical geometry—under which term are included surveying, levelling, plan-drawing, and other professional details of this order. The last year is devoted to the study of construction in theory and practice as applied to ordinary and hydraulic work. During the first three years the student is obliged to attend the school of architectural design ; and at the close of each year an examination in the subjects of that year's studies has to be passed before any farther advance is permitted. Before taking the degree of hydraulic engineer, two special examinations have to be passed : one private, which embraces the range of the last two years' studies; the other public, on three theses selected by the student himself from forty-five propositions prepared by the professors of mechanics, of construction, and of hydraulics. A fourth theme is prescribed specially by the professor of hydraulics, and is designed to test the practical knowledge of the young engineer. It is in the form of a project for a bridge, or a dam, or a hydraulic machine, or a canal ; and the student

is required to submit every detail, with regular plans, estimates of probable cost, and calculations of materials, &c. When these various tests have been satisfactorily submitted to, the student receives his diploma, and is entitled to exercise his profession either as a member of the government corps of civil engineers, or privately, as may suit his personal views. The names of the most distinguished pupils are each year submitted to the government, and published in the official gazette.

For the diploma of civil architect there is merely a difference in the extent, but none in the nature of the qualifications required. The surveyors, or "geometers," are generally simply practical men, who are the advisers of the irrigating class in all the subordinate details connected with the use and distribution of water.

About the middle of the last century, during the reign of Charles Emanuel III., an institution for experimental hydraulics, unique and interesting in its character, was organised by the exertions of Dominico Michellotti, one of the most eminent of the Piedmontese hydraulicians. It is established in a favourable position, at the distance of a few miles from Turin, and is provided with an abundant supply of all the apparatus required for experimental purposes. The professor of hydraulics is the chief of the establishment, and he transports his class periodically to the spot, and instructs them there in all those practical operations which are so much more readily understood when seen than when described. The immediate vicinity of the river Dora Ripaira, the existence of a canal drawn from this river, which flows under the walls of the establishment, the various channels which have been constructed within these walls, and the command of the great fall given by the position of the main reservoir, (which, with pardonable vanity, is described by Michellotti

as a *castello d'acqua*—a tower of water), give great facilities for experiments on discharge, contraction, velocity, &c. I had the pleasure of examining the establishment in company with its president, M. Richelmy ; and though I am not prepared to say that the results obtained, under conditions so unlike those of actual canals, could be of much practical importance, it is certain that to see the process of experiment with their own eyes, and to work with their own hands, must be most useful to the young students. It is very creditable to the Piedmontese government that this institution should be so liberally and efficiently maintained, as on my examination of it I found it to be.

Having filled my note-book with all kinds of details, procured plans of all such works as promised to be of interest and use, and, in fact, feeling that I had pretty nearly exhausted the resources of Turin, I left the capital for the provinces on the 11th of February ; and I confess I did so with great delight, as I had suffered too much in health not to detest the place most heartily. The day before I left, a very perfect and carefully-prepared list of the Italian authors on hydraulics was placed in my hands by Baron Plana, astronomer-royal, to whose kindness I was constantly indebted during the entire period of my residence at Turin. In my subsequent search for these works, I found M. Plana's list of the greatest assistance ; and as it may be useful to others, as it was to myself, I give it as an appendix to this chapter.

The locality to which I proceeded from Turin was Cigliano, in the province of Vercelli ; not only because it was a central point, whence the various canals might be visited with facility, but also because it was the residence of the Engineer-Inspector, M. Charles Noé, to whose kind offices I had been commended by the Count de Cavour,

then minister of agriculture, and now the enlightened and energetic minister of finance, and by the Chevalier Marioni, intendant-general of finance, specially charged with the superintendence of the irrigation department.

The Government of Piedmont has of late years taken every opportunity of obtaining for itself the proprietorship of canals; and the whole of those in the provinces of Ivrea and Vercelli are now the property of the state, and are administered under the agency-general of finance.

As a very large extent of the canals of the Vercellese was under the personal superintendence of M. Noé, the examination of them, under his guidance, was peculiarly interesting and advantageous. I need not now enter into details, which will be better given hereafter; but I may trace generally the route taken, and note the impressions left upon my mind by the works I saw.

Full of enthusiasm in his work, M. Noé carried me off, within an hour after my arrival at Cigliano, to visit the derivations of the canal to which this little town gives its name, and of the Canal del Rotto. Both these canals derive their supplies of water from the Dora Baltea, a stream which, in winter, carries a comparatively small volume of water, but in summer, when influenced by the melting of the snows in the higher regions of the Alps, becomes an important river. Its slope is very great; but, fortunately for the canal works, its bed is of hard, well-bound, and occasionally massive boulders or gravel. The derivation of the supply for the canal of Cigliano is made by means of an ordinary dam, carried right across the river, which, when I saw it, was undergoing the process of annual repair. In its construction there was nothing remarkable, as it was formed simply of massive stones bound together by timber sleepers, and protected in front and rear with piles. There had been some heavy floods

during the preceding season, and the limited extent of the damage done was fair testimony to the solidity of the work. Accustomed to see the tremendous action on the sandy beds of our Indian rivers, which invariably follows the establishment of any permanent dam or bar across them, I could not help envying the Piedmontese engineers their possession of rivers on whose beds such action was comparatively so small. Not that I found them free from this cause of anxiety, as they have occasionally catastrophes of the most serious character, involving sometimes the entire destruction of their works; but what is ever present with us is only occasional with them; and from this single circumstance of the comparative stability of the levels of the river-beds, the canals of Piedmont are relieved from one of the most formidable evils with which such works, in other irrigating countries, have to contend.

The regulation of the water admitted into the canal is effected by means of a sluice-bridge, with an effective outlet or escape attached to it. To close the canal, the sluice-gates of the regulator are dropped, and those of the escape outlet opened, when the entire volume of water passes of to the river by the latter. As abundant technical details of these works will be given in another place, I may only say here, that I found the adoption of a series of small sluices, such as are universally used in Piedmont and Lombardy, led to much greater facility in working the regulators than when the large and cumbrous gates used in India are employed. No Italian sluice is ordinarily more than about four feet in width; its depth is variable, being dependent on the average maximum supply to be admitted into the canal, but is rarely more than five feet. During periods of flood, planks, in sufficient number to exclude the surplus waters, are placed above the

sluice-gates. In India, on the other hand, the gates of our regulating bridges are twenty-one feet in breadth, from four to five in depth, and usually six inches thick, bound together by massive iron bars, and necessarily of great weight. Any one who has seen these manœuvred by a party of twelve men would willingly acknowledge how troublesome they are. In contrast with this state of affairs, I saw a single man open and close the sluices of the canal of Cigliano, which carries nearly five hundred cubic feet of water per second, in a few minutes, with the utmost facility. I think the comparative merits of the two plans are well worthy of the attention of the officers of the canal department in India; and I believe there are circumstances under which the Italian system might replace our own with great advantages.

The establishment of an escape outlet, between the regulating bridge and the dam across the river, is accompanied by an advantage of which my brother officers will appreciate the value. After every flood, M. Noé informed me there is invariably a considerable deposit of sand and gravel in the canal channel between the river and the regulator. The opening of the escape-gates, below which there is always as great a fall as can possibly be obtained, acts so efficiently as a scour on the part of the channel above referred to that the deposit is carried almost entirely away, and a very small part of it enters the canal bed. We have no similar arrangements for disposing of the similar deposits we always have; and the introduction of such a plan, as subordinate in its operation to the ordinary dam, seems to me to merit consideration.

The derivation of the supply for the Canal del Rotto, so called in commemoration of an irruption of the Dora into its channel, which threatened to wash it wholly from the face of the earth, is made in a manner similar to that

of Cigliano; and the various works of regulation are analogous in character on both lines.

The *permanent* establishment at the head of each canal I found to consist of a solitary guardian, who performed all the functions which, with us, require the services of a fixed body of twelve men, and the occasional aid of several more.

The scarcity of heavy material, for protecting the flanks and rears of their works, has led the Piedmontese engineers to employ an artificial stone, which might be made of use in many localities in India, where the want of like material is often of serious importance. It is locally called *prisme*, and consists merely of prismatic masses of a conglomerate, made with hydraulic lime and small gravel, in proportions necessarily variable according to the nature of the former ingredient. The masses are about three feet in length, and the side of the equilateral triangle forming the base of the prism is about fifteen inches. The ingredients are carefully mixed in wooden troughs of the dimensions and form above noted, and the *impasto* or mixture is left in these until it has set sufficiently to admit of its being moved. The blocks are then buried in the ground, at a depth of about eighteen inches, and are not considered to be in a fit state for use until they have been three years in that position. In the vicinity of the works, at the heads of the canals of Cigliano and del Rotto, I saw great fields of this material in various stages of maturity—the upper surface of the soil over it bearing, in the mean time, excellent crops of vegetables and grain. In all the river works I found it employed to a great extent, and with excellent effect.

It was impossible to pass along the banks of either of the canals just mentioned, without remarking how very indifferently the levels of the beds had been attended to

during their original construction. In some spots the slope was enormous, leading to such velocity of current as, in any other kind of soil than one of gravel or rock, must have caused the most serious erosion of the banks and channels. In other places, again, the slope was so much too slight as to cause the stream to become almost stagnant. It was evident that no great aid had been sought from science in the arrangement of these details; and it was fortunate that circumstances were such as to render this neglect, though often evident enough in its effects, and requiring in some localities special forms of work to counteract it, yet, on the whole, not of such serious consequence as in lighter soils it must have been.

The various bridges, outlets, escapes for drainage water, &c., presented no special features requiring notice in this place. I will only say, that the works seemed to me to be maintained by M. Noé in a most efficient and serviceable condition.

On the 12th February we drove to the provincial capital Ivrea, by a route which, following generally the valley of the Dora, led us past numerous scenes of great beauty and richness. The object of our journey was to examine the works at the head of the canal of Ivrea, the largest and one of the oldest in Piedmont, the date of its construction being about the middle of the fifteenth century. The town of Ivrea is a pleasant, cheerful-looking little place, picturesquely situated on the banks of the Dora, and commanding a fine view over the valley of the river. Just under the town, the long dam by which the supply of the canal is obtained, is seen stretching obliquely, like a huge black bar, across the river-bed. It is a massive structure of piles, woodwork frames, and immense blocks of stone of irregular forms, all bound together with great care. Though liable to very fierce attacks from the river,

it stands its ground well; and the annual repairs, which were in progress when I saw it, were by no means extensive. The bed of the river was admirably adapted for such a work, being hard, compact, impenetrable, so that below the dam there was scarcely any leakage, and the action of its down-stream end was extremely small. Nature has been in this, as in so many other instances, the best of assistants to the engineer, and the aid she affords has been skilfully taken advantage of. On the right flank of the dam there is a natural outlet, bounded on both sides by rocky banks. Through this the supply for the canals below is carried; and though it is spanned by a bridge, it is never closed. Some distance above the dam, the river is confined within bold, precipitous, and picturesque rocks. The stream bounds along with the velocity of a mountain torrent; but just before it reaches the dam itself, it is received into a large natural basin, which effectually moderates its force, and prevents its doing any injury to the works. The waters of the Dora bring down from the mountains considerable quantities of silt or sand, and some inconvenience was caused by deposits of this within the basin. But, by contracting the outlet, and constructing a masonry "spur" on the left bank, a scour, of force sufficient to keep the basin clear, has been established, and all inconvenience from this source has now entirely ceased.

I walked across the dam from one end to the other, and remarked with pleasure the solid, substantial, workmanlike manner in which it had been originally constructed, and was still maintained.

The regulator and its attached escape were similar in nearly all particulars to those at Cigliano and del Rotto, except that the sluice-gates were loaded with a cumbrous and useless wooden grating, by which they were raised

and lowered, instead of having a single iron upright, as on the latter canals.

In driving along the banks of the canal of Ivrea, I had numerous opportunities of examining the masonry falls employed here, as with us in India, to regulate the slope of the channel. Two forms of construction were employed—one exactly similar to that in use with us, in which the face of the fall has the form of an ogee, with revetment walls carried some distance down the stream, for the protection of the banks of the canal channel. In the other the drop of the fall is perpendicular, the water being received in a basin about four feet deeper than the level of the canal bed, and having a length which varied considerably. The effect of the basin in (according to the local phrase) "killing" the velocity of the water at the fall was very perceptible, the stream issuing from it at very little more than its ordinary rate. I watched the operation of this plan with a pleasant personal interest, as the idea of employing it had occurred to me just before leaving India, and the designs for such a work had been actually prepared. It was impossible for me, however, to carry them then into effect, and I have not heard whether my successor has done anything in the matter. I think the idea is one which might be usefully acted upon in many localities in our irrigating districts.

Having a great desire to see the interior economy of one of those large farms into which the irrigating districts of Piedmont are divided, I availed myself of the kindness of the Count de Cavour, who offered me every facility for the examination of a property of his, about eight or nine miles from Cigliano. On the 13th of February, and in company with my constant companion, M. Noé, I visited the farm of Leri, spending the day there with extreme pleasure and interest. Under the guidance of Signor Corio,

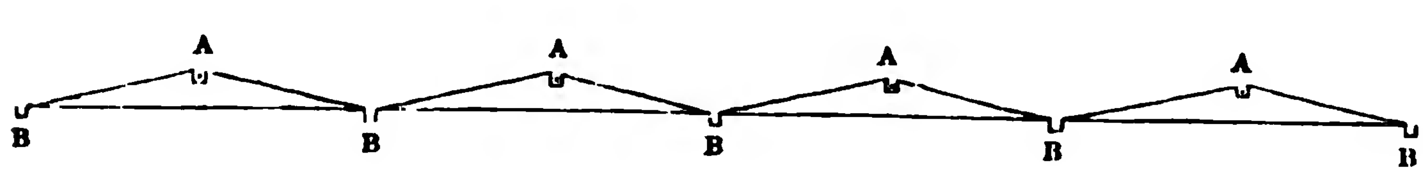
the tenant in occupation, a man full of intelligence and energy—a most prepossessing specimen of the highest class of the Piedmontese farmer—I examined the whole interior and exterior economy of the establishment. It was organised throughout with the utmost forethought and care. The whole labouring population employed were collected in a small village close to the farm-house, where clean and comfortable cottages were provided for each separate family. There was a neat little church, and an active *curé* for the care of their souls; a doctor and a dispensary for the care of their bodies; a wine-shop for the comfort of their hearts; and a school for the cultivation of their intellects. Their little domestic wants were supplied from the general store-shop of the village; and, if I might judge from the group of happy healthy-looking faces that crowded round to have a glimpse of the *forestiere Inglese*, I should say that their condition was in all respects a comfortable one.

My first acquaintance with the rice-cleaning machines (locally termed *piste*) of Northern Italy was made here. They are so exceedingly simple that I have little doubt they could be successfully introduced into those portions of the irrigating districts of India where rice is largely cultivated. A small stream of water gives motion to a common undershot wheel, about eight feet in diameter, of the most primitive construction. The axis of this wheel passes through the side wall of the mill into the interior; and by means of wooden teeth, fixed at intervals round its circumference, it elevates four (or as many more as are necessary) upright beams, the lower ends of which are covered with sheet-iron. At a certain height the beams are detached, and fall by their own weight into egg-shaped receptacles which contain the uncleaned rice. These receptacles are formed in a great block of granite,

one being placed immediately under each beam. The constant pounding the rice is thus subjected to breaks off the husk, which is then winnowed off from the pure grain. The process is, in point of fact, precisely the same as that employed all over the East, with the difference that here water does the work of women, who are the ordinary rice-cleaners there. Two men suffice for the charge of a *pista* of four uprights, which works night and day. The uncleaned rice is gathered in great granaries ; and as in the process of cleaning the grain is a good deal broken, the rice is itself separated and stored, according as it is in entire or fractured grains.

After visiting the huge stables full of Swiss cows, and the manufactories of cheese, butter, &c., in which so large a portion of the agricultural wealth of the irrigating districts of Piedmont consists, and admiring the neat and cleanly condition in which all were maintained, we wandered over the meadows, green as in spring-time, though not a leaf was to be seen around us. These fields were the *marcite*, or winter-meadows of Northern Italy—a species of cultivation limited, I believe, to the plains of Piedmont and Lombardy, and to which I have seen nothing similar in any part of the world which I have visited. The formation of these meadows, from which fresh grass is procured during the whole of the winter, is so interesting that I may give here a short general account of it, referring those who may desire more accurate details to a subsequent part of this work.

For the cultivation of marcite, the land is disposed in a series of small ridges and valleys. The section of a marcite meadow is given below. On the crest of each little



ridge there is a small channel (A, A, A), supplied with water from the irrigating water-course. The water from A, A, A, pours over the spaces A B, A B, A B (locally termed *ale*, or wings), in a thin but constantly moving veil. It is received into the drainage channels B, B, B, which are formed at the bottoms of the little valleys into which the marcite field is divided, and by these is carried away, and at a lower level is gathered into the general water-course, to become farther available for the irrigation of other fields. The breadth of the slopes or "wings" is generally about thirty feet, with a height at the centre of about one-tenth the breadth. These dimensions vary somewhat according to local circumstances; but the proportion between the breadth and height of the slopes, as given, is generally maintained whenever practicable. The constant passage of the water over the roots of the grass stimulates the growth greatly; from which cause, and also from the fact that the moving water carries forward with it a portion of the rich humus of the soil, the process is found to be a very exhaustive one for the ground. Twice a-year the marcite fields are, therefore, abundantly manured; and there are, as a general rule, five crops of grass obtained from them during the year. To dispose the surface of a field so as to fit it for marcite, costs from £10 to £12 per acre under ordinary circumstances; but in some cases, where the movement of soil and the cost of works for the supply of water are great, the expense rises to £40, and even £50, per acre. Signor Corio estimated the *net* value of the annual produce of an acre of marcite at about 150 francs, or about £6.

From the marcite fields to the rice grounds was a natural transition. These latter I found arranged in precisely the same manner as the rice fields of India, being each enclosed by low mud walls, about fifteen or eighteen

inches high, furnished with inlets and outlets for the process of irrigation. At the time I saw them they were being ploughed, and in all cases the soil was of the same dense, heavy, argillaceous nature, which is preferred in the East for the same cultivation. In sight of the rice lands, it was impossible not to have one's thoughts drawn to the question of their influence on the health of the working population. I found the impression of their unhealthiness, I may safely say, universal—the time of cutting the rice, in the autumn, being distinguished as the period of fevers, occasionally of great severity. It was, however, an opinion equally general, that when the proprietors of such lands interested themselves actively on behalf of the labourers employed in their service, in supplying them with good and plentiful food, and providing them with dwellings removed from the immediate vicinity of the flooded lands, the results were invariably most satisfactory—not only the amount but the intensity of the unhealthy influence being much reduced. The legislature of Piedmont is at this moment occupied in devising a law for the better regulation of rice cultivation; and as there is an earnest desire to combine the manifest advantages of so profitable a species of culture with every precaution for the health of those employed upon it, there is reason to hope that a good result will follow their efforts. There is no chapter in the agricultural history of Northern Italy more curious than that of sanitary legislation as connected with water-meadows and rice-grounds, both of the highest value in that country; and as the interest of the question is as great to the inhabitants of India as to those of Italy, I have recorded all the information I possibly could find connected with it, and will give it hereafter. Meanwhile, I will only say that, in passing through the irrigated districts, I took special care

to observe the outward appearance of the population, particularly the women and children, whose more delicate organisation makes them always the best indices of the sanitary state of the district in which they live. As the general result, I must say that, at the time of year when I saw them—namely, in the beginning of spring—I have rarely seen people who appeared to be in a better state of health than the labouring population of the irrigated districts of Piedmont. I am bound to specify the time of the year, as I was informed by trustworthy authorities that in autumn the circumstances were different. It is farther to be noted, that the principal sufferers are not the fixed population of the districts, but the labourers who come from the high countries, as the Irish do to England in harvest time, to supply the increased demand for labour which then arises. By general agreement, these poor people were exposed to malarious influences, under circumstances of personal discomfort and exposure which were sufficient to make the ravages of fever easy to be acounted for. In all the discussions I had opportunities of examining, I found great want of exact information: no statistics of health and disease in the irrigated tracts, worthy of the name, were to be found; and the statements at once of the advocates for and against the system of irrigation were far more declamatory than numerical. I have only space for a single illustration of my meaning. In a work on the subject, crowned by the Royal Agricultural Society of Turin in 1845, I found statistical tables which, on analysis, established, or seemed to establish, the fact that, in the rice districts of the Lumellina, the mortality was such *that the population ought to become extinct in about fifty years.* In point of fact, however, I found, on careful discussion of the results of the official census, the population of this province, instead

of decreasing, had been steadily on the increase; and that during the twenty years between 1819 and 1838, the increase of population, in the rice-producing districts generally, had been greater than in any other portion of the kingdom. The province of Vercelli, which is largely irrigated, shows, with the single exception of Savona, the highest ratio recorded, giving an increase since 1819 of 0.41, while Lumellina is 0.31, and Novara 0.29. Throughout the kingdom generally, the ratio of increase for the same time amounts only to 0.19; so that the superiority of the three great irrigated districts to the average is very marked. The case I have adverted to was only one of several which attracted my notice, and impressed upon my mind very strongly the necessity of accepting the statements, made on either side of the question, with considerable reserve.

After a long day spent at Leri I left it, with the pleasantest possible impressions of my intelligent host and his interesting charge. "You are the first Englishman," he said to me in parting, "I have ever spoken to; and, *per Bacco!* the more of your countrymen you send here the better. I'll welcome them all!" And so drinking each other's healths, after the fashions of our respective lands, we shook hands heartily, and parted with feelings which I am sure were mutually of the kindliest character. The main roads of Piedmont are among the best in the world; but of all the by-roads I ever travelled over—and I have now had experience of these in three quarters of the globe—I do not hesitate in pronouncing that from Leri the very worst it was ever my fortune to see, and, I may add, to feel. I look back with a sort of wonder to our ever having emerged at all from its yawning gulfs. Our having done so must, I suspect, be in part, at least, attributed to the exhilarating effects of the hospitality of the day!

I need not dwell much longer on my examination of the canals of the Vercellese. I had opportunities of examining characteristic examples of every variety of work in use, and of having their peculiarities explained to me with a patient care, for which I must ever be grateful. Perhaps, before passing onwards, I may state briefly the impression left upon me by my examination of the apparatus in use for the measurement of water on the canals in this province. The varieties of form in this apparatus will be described hereafter. The chief ends at which every form aims, are to cause the water to issue from the outlet with *no velocity*, and under an invariable head of pressure —thus bringing the practical problem of the calculation of discharge within the conditions best adapted for the use of the formulæ in which most confidence is placed. Now, in point of fact, after examining, I may safely say, hundreds of examples of regulated outlets, supposed to discharge fixed quantities of water, I must frankly state that I did not find one which was perfectly trustworthy. In every case, some of the arrangements which were required to destroy the velocity, or to maintain constant the head of pressure, were wanting; and it could admit of no doubt that the actual was materially different from the supposed discharge. It is one of the wisest and most valuable of the provisions of the civil code of Charles Albert, that the differences in quantity, arising from the state of affairs just adverted to, are recognised and provided for. It is forbidden to the courts to entertain suits on water supply, unless the difference in dispute is more than one-eighth of the calculated discharge, whether in excess or defect. With this provision, which includes, I think, the ordinary limits of fluctuation between real and theoretical discharges, with the forms of apparatus generally employed, I am of opinion that the system of distri-

bution established in Piedmont, with all its admitted imperfections, is still of great practical value. It is of the utmost importance to have *any* regulated system of distributing and measuring the water issued to the cultivators: the defects which exhibit themselves in practice may be corrected as knowledge increases; but where, as with us in India, there is no measuring apparatus whatever worthy of the name, the wastage and injury, scarcely less to the employers than to the proprietors of the water, are great and deplorable. Such wastage exists in Piedmont as well as in India; but in the former case its limits are much restricted by the number of precautions adopted against it, while in the latter, restriction can scarcely be said to exist. In regard to rice cultivation, the supply of water is altogether from unregulated outlets. The supply given is only limited by the necessities of the crop; and the payment for the quantity thus given, which does not admit of calculation, is invariably made in kind—*i. e.*, by a certain proportion of the gross produce of the land, which varies much according to locality and other circumstances, rising in some cases as high as one-third, and falling in others to one-tenth of the crop. The canal revenues being rented for periods of nine years to a contractor, enormous quantities of rice in the husk are annually collected at the government mills of Salasco, where, when I visited them, there were six or eight water-wheels, each working from four to eight *piste*, in continual action; and huge granaries were filled with the grain in all stages of progress. The scene at these mills, in harvest time, was described to me as one of great excitement and bustle: numbers of carts are seen arriving from all parts of the province, loaded with the quotas of produce due by their proprietors to the contractor—for the rice must be delivered at the mills by the cultivators. A large establish-

ment are busily employed in registering, measuring, and storing the grain. A crowd of men, women, and children, full of the joyous excitement which so naturally and pleasantly marks the successful close of the time of gathering, when men's hearts are glad within them in sight of their year's work ended and rewarded, fill the vast court-yard, and pass merrily among them the wine-cup, or join in dance and song—the excitement being probably quickened by the thought that, as the harvest is now brought home, the dangers of the fever season need no longer be held in dread.

I found, however, throughout the province, general dissatisfaction with this system of payment in kind—a result which is not to be wondered at, for the plan is accompanied by many serious disadvantages. There is a constant struggle going on between the Government contractor and the cultivators. The former has numerous agents, who, in time of harvest, when the crop is in the ground, select their employer's share of the produce, and, in looking after his interests, doubtless find means to advance their own at the same time. There is, accordingly, a great deal of interference with the cultivators, which had much better be avoided; and I cannot myself see any reasonable objection against commuting the payment in kind into a just and reasonable payment in money, and thus leaving the cultivator free from all interference on the part of the contractor's agents. It was not only, however, the payment in kind which seemed open to objection, but the general system of renting the whole waters of the province to a single individual must be productive of serious inconveniences. It places in one man's hands an enormous amount of power; and from all I saw and heard, there was reason to doubt whether an appeal to the local tribunals was an efficient check on the possible misapplication of such power. There was certainly a

strong feeling expressed against the existing arrangement; and I think it would be found preferable, both as regards the financial interests of the government and the free development of agriculture, were the state to administer the canals directly by means of agents of its own, having no personal interest in the results. At present, the decision of all disputed points rests *practically* with the contractor, and he is a party too directly interested to command the confidence of the agricultural community.

Having spent nearly a fortnight in the examination of the canals under charge of my kind friend, M. Noé, I left the Vercellese for Novara on the 24th of February. I had been provided with several letters of introduction to engineers and others in the latter town by General the Baron Solaroli, with whom I had the pleasure of a previous acquaintance during his service in India, and whose efforts to assist me in my work were unwearied. I was, however, unfortunate in finding the gentleman to whom my letters were addressed absent from Novara, and I was accordingly thrown on my own resources.

The most important canal in the immediate vicinity of Novara is the canal Mora, so called as having been enlarged and repaired in 1481 by Ludovico Sforza, duke of Milan, surnamed "The Moor," from his dark complexion. This canal I visited and examined, without, however, finding any of the works worthy of special note. Indeed, I could not avoid noticing the inefficient state in which the works here were maintained. Most of the outlets of distribution which I saw were made of wood, and the few I observed in masonry were not provided with any means of regulation. The slope of the bed was excessive; the channel and banks were much eroded; and the former was exceedingly irregular in its form. Rude dams of fascines were permitted in the interior of the canal, which, when,

I saw them, were causing serious damage to the bed and banks in their neighbourhood; so that altogether the impression left on my mind was not satisfactory. The canals in this part of Piedmont are generally—I may say exclusively—private property; and they are certainly not administered in the same efficient manner as those under the control of the State. This impression was confirmed by subsequent inspections of the canals Busca, Biraga, Langosco, and Sforzcesca, all within a short distance of Novara.

Throughout the irrigating districts of Piedmont there is a source of supply of water, subordinate indeed to the canals, but still of the highest value and interest. This is the supply from springs, or *fontanili*, as they are locally termed. The whole surface of the plain, between the Po and the Alps, appears to be underlaid by a water-bearing stratum, which is reached at different depths in different localities. From this stratum, springs rise in many places, and in considerable volume. The sources of each are enclosed within large wooden tubes; and the waters from several such sources being collected in one channel, a supply sufficient for the purposes of the farmer is thus procured. Being derived from a considerable depth beneath the surface of the soil, the temperature of the water of the *fontanili* is always higher in winter than that of the canals; and hence it is greatly preferred for the irrigation of the *marcite*, or winter-meadows. I cannot specify the exact quantity of water derived from this source; but the numbers of springs which in every direction meet the eyes of the traveller through the provinces of Vercelli, Novara, and Mortara, indicate how important a part they play in developing the resources of these rich and flourishing tracts.

CHAPTER II.

THE LOMBARDO-VENETIAN KINGDOM.—PROVINCES OF MILAN, LODI, CREMONA, MANTUA, VERONA, BRESCIA, COMO, AND PAVIA.

HAVING now seen all that it seemed important for me to see in Piedmont, I left this interesting country on the 27th February; and crossing the Ticino by the noble bridge at Buffalora—a record of that Kingdom of Italy to which, even now, the Italians look back with feelings of pride—I entered the magnificent plain of Lombardy. The Austrian custom-house authorities were courteous and obliging; and having satisfied themselves that my books on irrigation contained no inflammable or revolutionary matter, a few minutes sufficed for the examination of my baggage.

I was soon made aware of the noble scale on which the hydraulic works of Lombardy have been constructed, by seeing the *Naviglio Grande*, or Great Canal of the Ticino; an artificial river which, constructed so early as the twelfth century, has for more than six hundred years borne onward a volume of water equal to nearly 1800 cubic feet per second. This great mass of water has been spread over the surface of the country through a thousand channels, stimulating the productiveness of the soil to such an extent as to make the country through which it passes one of the richest and most densely populated which the

world has ever seen. It was impossible to look for the first time on this great work—the father, as it were, of the irrigation canals of modern Europe—without some feelings of emotion. And when the amount of social and national benefit which it has been the means of conferring, through long periods of varied fortune, is recalled to mind, one feels a willing sympathy in the pride with which it is regarded by the descendants of its original constructors.

Along one of those fine highways by which Lombardy is distinguished, between interminable rows of most unpicturesque-looking poplar and mulberry trees, and through sheets of meadow land, covered with rich crops of grass, we approached the city of Milan. Huge carts, with their long teams of heavy horses; groups of peasants, in carriages of the most indescribable character; parties of that varied soldiery which forms the present army of occupation in Lombardy; policemen on horse and on foot, and travellers of every grade, covered the road as we came near to the capital. It may have been fanciful, perhaps, but I thought I observed on every Italian face there was cloud—a look of suffering and discontent. It is certain that nothing could have been more sombre than the aspect of Milan itself, with its half-deserted streets, its squares full of German soldiery, and occasionally bristling with cannon. It was sad to see a place, once so famous for its cheerful gaiety, thus overshadowed and depressed.

On reaching the city I found myself placed in a somewhat awkward position. Although I knew a letter to the Government of Lombardy, from the Austrian minister of foreign affairs at Vienna, had been applied for on my behalf, I found that no such letter had yet reached Milan. Under these circumstances, I thought that the frankest policy would probably be the best; and so, hav-

ing sought and obtained a personal interview with Prince Carlo Schwartzenberg, then the governor of Lombardy, since removed to Transylvania, I explained to him the object of my visit to the province, and solicited such assistance as it might be in his power to give. I have very sincere pleasure in bearing my humble testimony to the courteous and cordial manner in which this application was received and complied with. I had no difficulty in understanding how it was that, even by those most opposed to the system he was bound from his position to enforce, the governor's kind, frank, soldier-like manner, and high personal qualities, were appreciated and acknowledged. I found, during my subsequent travels, that whatever assistance I sought from the government officials was willingly granted. Some annoyance I certainly did receive, from becoming, after Prince Schwartzenberg's departure, an object of notice to that despicable spy department, which his successor seemed to have stimulated into unusual activity. I was, of course, much occupied in making notes on various subjects connected with my duties. These, being made without the slightest attempt at secresy, had been noticed by some of those wretched *employés* of the police who haunt the footsteps, not only of foreign travellers, but of natives also. I found my employment had been misunderstood, and that it had been reported to the chief police-office at Milan, that I had been making notes on, and taking plans of the various military works in the country. As I had most scrupulously restricted myself to the civil duties with which I was charged, I was naturally indignant at being subjected to a charge so groundless and untrue. I was warned that all my papers were to be examined by police agents—a matter about which I was perfectly indifferent, as I had not a single note or plan to

which even the most jealous could have taken exception. In the meanwhile, however, my letter from the foreign minister at Vienna came to hand; and on my delivering this to Count Strassoldo, the new governor, I heard no more of the threatened visit from the police. This affair annoyed me much, as, had it not occurred, I could have reported, and would have done so with pleasure, that, travelling through the whole of Lombardy, and part of the Venetian provinces, with no other recommendation to the notice of the Government than that I was an English officer and a stranger, I had received every courtesy from the Austrian authorities. As it was, I brought away an intense dislike to that system of morbid government under which the fair provinces of Lombardy are now crushed almost to despair.

The city of Milan is encompassed by the waters of canals, which on the one side connect it with the Adda, and on the other with the Ticino and the Po. The Naviglio Grande terminates under its walls. The Naviglio Interno, occupying the former ditch of the ancient town, furnishes an inner line of navigation, by which heavy supplies of all kinds are transported, and links the Naviglio Grande with the Naviglio della Martesana, the important line connecting Milan with the river Adda. From the southern side of the city, the magnificent canal of Pavia—one of the greatest of those public works which Napoleon bestowed on Northern Italy—pursues its course towards Pavia; while numerous smaller channels, supplied directly or indirectly from the great arteries just mentioned, co-operate in producing that wondrous fertility which at once attracts the traveller's notice when he first visits the neighbourhood of the city. Among the smaller channels, the most remarkable is the Vettabbia, the escape line of the Naviglio Interno, and the receptacle, at the

same time, of a large portion of the sewerage of the town. With its waters, so rich in fertilising matter, the adjoining meadows are irrigated, and produce no less than eight crops annually, of which five are grass and three hay. One of the farms watered from this stream, which I visited, gave a rent of 30 francs per *pertica*, or nearly £8 per acre; and this was considered a moderate amount, there being farms in the immediate neighbourhood which were rented at from £15 to as high as £22 per acre. Results like these, however, were confined to a very narrow circle, including not more than a few square miles immediately around the city. It was only at Milan that I found the sewerage waters utilised. In the other large towns which I subsequently visited, I found no measures taken to benefit by the drainage or the refuse they supplied. Even at Milan it is a portion only of the proceeds of the sewerage which finds its way to the Vettabbia. The stable manure is either sold directly, or sent by the proprietors to their farms in the vicinity. The produce of the street clearances is eagerly sought by the cultivators of the higher lands to the north of the city; while house manure of different kinds is carried away by another class of cultivators, who apply it chiefly to the market gardens around the town. The subterranean channels which communicate with the Vettabbia carry off, therefore, only a limited portion of the animal and vegetable refuse which Milan supplies; and it is a mistake to consider this city as an illustration of the utilisation of such products on a large scale. There will be no difficulty in understanding the cause of the fertility of the districts adjoining the great towns of the Lombardian plains, when it is borne in mind that in the triangle included between Milan, Lodi, and Pavia, each side of which is little more than twenty miles in length, there are, it is estimated, not

fewer than 100,000 head of cattle, 100,000 pigs, and 25,000 horses, in addition to the human population. It is to the immense supplies of manure, solid and liquid, obtained from these sources, and not to the refuse of the towns themselves, that the richness of the soil is mainly attributable.

During the fortnight I remained at Milan, I took opportunities of visiting all the canal works in the vicinity. On the Great Canal, and the Canal Martesana, I found numerous examples of that *modulo magistrale*, or measuring apparatus, which is considered by the best authorities to fulfil most perfectly the conditions required in such works. I shall have to give hereafter minute details of this celebrated apparatus; but I may remark here, that as in Piedmont, so in Lombardy, I found much discrepancy between theory and practice. In the great canals under charge of the Government, I found the normal form of the measuring apparatus adhered to with considerable accuracy; but on the private canals, of which there are an immense number, all kinds of arbitrary modifications were permitted. The most important parts of the apparatus were occasionally omitted altogether; or when not omitted, their dimensions were modified in such ways as materially to affect the action of the works. In its best form, and with all its parts complete, I consider the *modulo magistrale* of the greatest utility; and I think it might be introduced into the canal system of India, with great benefit both to the cultivating community, and (as checking wastage of water) most especially to the Government.

The locks which connect the Canal Martesana with the interior canal of Milan must always be regarded with a peculiar interest, not merely as being among the very earliest of this class of works constructed in Europe, but

because, by a trustworthy tradition, Leonardo da Vinci is held to have been their designer and constructor. The completion of the line of canal between the Adda and the city was effected during the reign of Ludovico il Moro, a period most fruitful in works of irrigation and navigation; and at this time Leonardo is known to have held the appointment of ducal engineer. The first invention of the lock has even been claimed for him; but this idea is now altogether abandoned, there being documentary evidence in existence which proves that locks were in use probably before he was born. A tradition, however, which links his illustrious name to the hydraulic works of Milan, is naturally cherished and maintained; and there seems no good ground for doubting its correctness. With that wonderful versatility of genius which has been so marked a characteristic of the highest class of Italian intellect, Leonardo da Vinci has written on hydraulics with a remarkable knowledge of the subject. His work, "*Del Moto e Misura dell' Acqua,*" in nine books, is now before me; and it is impossible to look into it, even cursorily, without being struck by the close observation and power of analysis it exhibits. There are some fanciful speculations, and not a few obscure passages in it; but such a work, in its integrity, undoubtedly shows singular knowledge on a subject which seems to us so extraneous to the other pursuits which have rendered its author so famous. We sympathise with the feeling that leads the hydraulic engineers of Lombardy to rank Leonardo da Vinci among the fathers of their profession, and to claim for him high credit both in its science and its art.

In the financial administration of the great canals, which may be regarded as the main arteries of the irrigation system of Lombardy, it has been the almost invariable practice of the Government to sell the water in absolute

property to the possessors of the soil. Whatever may have been the motives in which this policy had its origin, there can be no doubt of its having operated most beneficially for the country. The great families, who are the landed proprietors throughout the irrigated districts, having the capital to expend on the construction of those minor works required for the interior distribution of the waters, found in the perpetual right of possession granted to them by the State an inducement to invest their funds in such works, and a guarantee for the returns to be derived from them. So soon as the water passed beyond the banks of the government canal, the purchasers had unrestricted liberty to dispose of it as they chose; the *diritto di acquedotto*, or right of passage, secured to every proprietor of water the power of carrying his channel, under certain specified conditions, across all lands intervening between the main canal and his own property; and when the supply purchased exceeded the immediate wants of the purchaser, he had the right to dispose of the surplus to such of his neighbours as were desirous of having it. Under this system, it is astonishing to see the extent to which minor canals have been executed. The whole surface of the country is covered by them as by a dense net-work. At all levels, and by the use of various ingenious works, they pass over, or under, or through each other, in such ways as to preserve individual rights uninterfered with, though the result, to outward appearance, is a system of such marvellous complexity as to make the observer conclude it must lead to interminable disputes. The designations of the canals, the farms, the villages of these rich districts, carry the thoughts constantly back to those dim historic times when Roman families possessed the land, and even then executed the works which preserve their names from oblivion. Such

titles as the Muzza, Fusa, Villa, Pompeiana, Corneliano, Albuzzano, Terenzano, living still and in present use, have changed but little from their Roman originals—Mutia, Fusa, Pompeia, Cornelia, Albutia, and Terentia. Modern families still continue to bestow their names on the channels they execute; and the Cavo Taverna, the Naviglio Pallavicino, the Cavo Belgioso, with many others, will remain to future times as records of private enterprise and professional skill.

It may perhaps, however, appear singular that in a country where water is so valuable, these private canals, of which I have been speaking, have rarely or ever been directly profitable to their original constructors. The number of works required is so great, the payment for the land occupied so heavy, the various legal and general expenses so considerable, that the direct returns from the smaller canals of irrigation are, for many years after their construction, insufficient to pay any interest on the capital expended. It is to the indirect returns, to the improvement of the soil, to the power of replacing inferior by superior kinds of cultivation, that the proprietors look, in the first instance, for their reward.

I had an opportunity of examining, in great detail, the Cavo Lerino-Marocco, one of the largest private enterprises in Lombardy, for which I was indebted to Professor Antonio de Kramer, one of the most delightful and intelligent of those Lombard gentlemen to whose kindness I was constantly laid under obligation.

Derived from the Canal Martesana, and carrying a volume of water equal, in summer time, to nearly two hundred cubic feet per second, the Cavo Marocco flows in a generally south-easterly course from Milan towards Lodi, through the richest tracts of meadow and arable land. Its entire length, including its various branches,

was estimated to me by the engineer in charge, M. Calvi, at, in round numbers, about 150 miles; and the same authority calculated its entire cost, including every expense, at nearly £1600 per mile, while its repairs and maintenance cost about £20 or £25 per mile per annum. No work would give the student of the Italian system a better idea of its singular details than this. The almost unlimited number of branches diverging from the main stream; the perplexing way in which the water drawn out of the channel was returned into it again, by taking advantage of even the minutest differences of nutural or artificial levels; the crossings and recrossings of the various streams; in a word, the wondrous plasticity of the entire system, were most curious to see, and almost impossible to describe in such manner as to give a true idea of the actual state of affairs.

The financial history of this interesting work is one of perpetual struggle; two generations of proprietors have been exhausted in the effort to complete it. The original proprietor, whose name the canal bears, must have been a man of indomitable perseverance; for I believe he alone, of the members of the association by whom the project was commenced, remained firm in his adherence to it, and his family are now the possessors of the whole. The entire fortune and credit of M. Marocco, who was a distinguished lawyer in Milan, were devoted to the canal, and his descendants are beginning to reap the advantages of his energy and singleness of purpose. His story is, in truth, a reappearance, in canal annals, of that of the Duke of Bridgewater; and I hope the ultimate reward will reach the family of the Lombard, as it has done that of the Englishman.

In examining the various works (whose constructive details presented nothing very peculiar), I could not help

fancying I saw, in their somewhat untidy condition, indications of that financial pressure under which the scheme had laboured since its commencement. Although, doubtless, perfectly efficient for the objects required of them, there was a poverty-stricken look about all the bridges and aqueducts, and other works I saw, which arrested the attention at once: they all looked out of repair; and some of them, to outward appearance, would have been pronounced almost unsafe. I remember one wooden aqueduct, which looked so very near destruction that crossing it was not quite pleasant. But these were merely external appearances, as the structure, when examined, proved sound and substantial enough. Of course I saw on this line a very large number of *moduli*, or distributing edifices; and I must frankly state, that I did not see *one* which was complete: some part or other of the apparatus was invariably wanting. A very general plan was to make the dimensions just one-half of those of the normal form; but even this rule was by no means invariably preserved. In all the private agreements between the proprietor and employer of water, great latitude is allowed as to the methods of measuring the discharge; and, except on the great State canals, there seemed to me to be no fixed plan of any kind. In a great many instances, I observed that the outlet was merely a longitudinal opening, having a fixed height of four inches, and a breadth variable according to the quantity of water in local *oncie* which it was supposed to discharge, a breadth of three inches being allowed for each *oncia*. The outlet was cut in a slab of stone four inches thick; and, at two inches above the upper edge, a line cut in the stone marked the fixed height, or, as it is termed on the spot, the *battente*, at which the surface-water of the canal should be maintained to insure the correct discharge. A

strong iron rim protected the edges of the outlet from being tampered with; but beyond this no other precaution was observed. It is very clear that no great accuracy of discharge could be expected from such forms of apparatus as this; but M. Calvi informed me, that in practice the employers were generally content; for if they occasionally had less than their due, there were also times when they had much more; and so a kind of rude system of adjustment was established, which prevented any serious complaints.

The vicinity of Milan is remarkable for its abundance of irrigating springs, or *fontanili*—some of very considerable dimensions. I was taken by M. Mazzeri, one of the most eminent of the Milanese engineer-advocates, whose acquaintance I had the pleasure of making, to see one situated about two miles from Milan, which, as an example of the class of works, may deserve a brief notice. Its head was formed by an excavation about 200 feet long, 100 wide, and about 8 deep. At this depth the water-bearing stratum was reached; and over the surface thus laid open, no less than forty-two separate springs, each enclosed within its wooden case, were to be seen throwing their small supplies into the main reservoir. The united discharge of the whole amounted to the considerable quantity of nearly 12 cubic feet per second, which, at the ordinary value of water on the spot, was worth in all very nearly £4000. Some of the wooden tubes, or *tinelli*, as they are termed, were of unusually large dimensions, being as much as 8 feet in diameter. But this is in practice found to be too much, the expense of sinking them being excessive, as only one man can work at a time with an instrument which is like a magnified hoe, and is, in fact, precisely the same as the Indian *jham*, by which the undersinking of masonry

wells, under circumstances analogous to those of the Milanese *tinelli*, is effected. M. Mazzeri informed me, that to sink one of these huge tubes to the necessary depth of about 12 feet, through the hard gravelly soil, required about five months' daily labour. The sides of the excavation for the fountain-head were neatly finished, turfed, and, where necessary, revetted with planks. Trees were planted round the edges; and the whole place had a pleasant, fresh, and rather picturesque look, with its clear pure stream, drooping foliage, and constant gurgling of the spring waters. After flowing about half a mile in excavation, the water reached the ordinary surface of the soil, and was then employed in irrigating, at the time I visited the spot, about thirty acres of very fine *marcite*, or winter-meadows. After doing so, there still remained about 10 cubic feet per second for employment on lands at inferior levels. In thus using spring-water for marcite, it is calculated that, under average circumstances of soil and climate, about one-seventh of the total supply is lost either by absorption or evaporation. The remaining six-sevenths may continue to be used, if there are lands so situated in regard to levels as to be able to receive it, in which case there is little or no waste; but if there are no lands so situated, the waste of water in marcite cultivation becomes excessive, amounting, in fact, as just shown, to six-sevenths of the whole available supply. In passing over the marcite fields, I was struck by the very marked difference, both in quantity and quality, between the grass in the fields first watered and that in those more distant. On seeking an explanation of this from the very intelligent tenant-farmer who accompanied us, he told me the difference was always observable, and that the farmers attributed it to the greater stimulating effect of the water on first leaving the fountain-head, owing to

its higher temperature. Noticing, also, considerable differences in the slopes given to the marcite fields, I was told that, in practice, a slightly increased velocity of the water in passing over the meadow was found to compensate for the deficiency of heat, and that hence the distant fields had larger inclinations given them. I may say in passing, that though part of their theories might not on all occasions have satisfied scientific agriculturists, I found constant cause to admire the strong practical sagacity and large acquired information of the Lombard tenant-farmers with whom I was thrown in contact. They were generally self-taught men, who had raised themselves, by perseverance and probity, to the comfortable positions they held. They seemed to me a most estimable, as I found them a most hospitable, class of men; and I carried away impressions of them of the most pleasant kind.

The resources of Milan in hydraulic literature I found to be extensive and valuable, and I was able to collect there a tolerably complete series of works on the various subjects embraced by it. During the long series of years which have been devoted by many of the most eminent mathematicians and engineers of Italy to the study of this branch of science, a large mass of literature has naturally accumulated. The social importance of irrigation, by creating an extensive class of readers, has continued the demand for such works down to the present day; and collections of the various authors, ancient and modern, continue to be periodically published. The most complete, under the title of "*Nuova Raccolta d'Autori Italiani che trattano del Moto dell' Acqua,*" was published at Bologna by Francesco Cardinali. The work consists of two parts: the first, in ten quarto volumes, published at intervals between 1821 and 1826, contains the works of all the more ancient Italian writers; the

second, in six similar volumes, to which the term "Nuova" is more specially applied, gives the works of the modern authors up to 1829. A seventeenth volume, published at Florence in 1847, completed the series of what may be called the classics of hydraulic literature. Of this work I obtained a perfect copy in good order: its typography and plates are old-fashioned, and not very good; but there is an invaluable mass of information on every subject connected with the science and art of hydraulics contained in it. Considerable activity has, during the last twenty years, been shown by the Lombard engineers, and a number of valuable practical works have been published by them. Among these there are two historical works of interest, one "*The History of the Canals of Navigation*," the other "*The History of Canals of Irrigation*," in the Milanese, by Guiseppe Bruschetti, a distinguished living engineer of Milan—though at this moment, like all the best intellects of Lombardy, an exile in a neighbouring state. From these two works I have derived much assistance in studying the historical part of the subject, though I confess I found M. Bruschetti's style occasionally rather cumbrous and obscure. The great number of cotemporary records he has collected throws much light on the earlier history of irrigation; and in the sketch of this I have ventured to give, I have availed myself gladly of his labours. An excellent little "*Practical Manual*," which is full of useful formulæ and tables, has been published by M. Columbani in 1845; and to this work I have had repeated occasion to refer.

To an officer familiar with the fiscal system of the British government in India, it was peculiarly interesting to find that a system similar in principle, and worked out in a way almost similar in practice, has been long established in Lombardy. The "*Censimento*" of Lombardy

is the *Revenue Survey* of those parts of India in which the Government demand has been permanently fixed. The terms in both instances imply a minute and carefully-recorded survey and description of the country, wherein every separate field is noted in its dimensions and its capabilities, and classified according to its condition at the time the description and survey are made. In Lombardy each class of soil is valued at a certain number of *scudi*, or crowns; and by this value the Government demands are regulated. It seems to me, however, that the system of taxation in Lombardy, as based on this minute estimate of the value of the soil, is much worse for the cultivators than the permanent settlement of India; for the Government, in the former case, reserves to itself the right of raising its demand at will, preserving only, as the means of distributing this demand, the proportionate values of the different classes of land as established by the *Censimento*. Thus, within the last few years, the Austrian Government has, as a penal measure, added at once fifty per cent to the previously existing amount of the state taxes on the land; and the only advantage the proprietors have is, that, this demand being regulated by the original estimate of the survey, those who have improved their properties most during the time that has elapsed since that estimate was made, feel the present pressure least; though even with those best situated in this respect, it is far higher than is consistent with the permanent prosperity of the country, and has, in fact, nearly annihilated that spirit of improvement of which so many honourable records remain. In the Indian system, on the other hand, the Government, equally bound with that of Lombardy to regulate its demands by the proportionate value established by the survey, has farther bound itself to alter, in no way whatever, its demands for a period

of thirty years; and the general conviction of the advantages of moderate assessments is so decided that, even at the period when it is permitted to modify the amounts claimed, the alterations are quite as frequently to decrease as to augment the tax. On the details of the *Censimento*, historical and practical, I obtained several works, considering the subject one of interest to officers connected with the revenue system of India. An old book, published at Milan in 1784, by Sig. Don Gianrinaldo Conti Carli, under the title of "*Il Censimento di Milano*," gives historical details from the end of the twelfth and commencement of the thirteenth centuries, when the first rude attempts to establish the system were made by the Republic of Milan, through the agency of foreigners (employed because of the general jealousy of natives), down to the time of Maria Theresa, when the existing survey and estimate were completed and established as the law of the land. For the practical details, two works may be consulted—one published at Milan, in 1810, by the Direction-General of the Censo, and entitled, "*Istruzioni della Direzione Generale del Censo ai Geometri incaricati della misura dei Terreni e formazione della mappe e de Sommarioni in esecuzione del R. decreto*, 13 *April* 1807." The other, under the title "*Il Sistema Pratico del Censimento Prediale Milanese*," by Gaetano Tarantola, engineer, also published at Milan in 1816, gives a very complete summary of the whole subject, with illustrative tables and maps.

There is another class of agricultural institutions established in Lombardy, which seemed to me worthy of study—those, namely, by which the relations between the landlords and tenants of the country are regulated. I hope it may not be considered tedious if, while reserving minute details for a more appropriate place, I give here a sketch of the institutions referred to.

In letting their farms, the proprietors of Lombardy generally adopt one or other of the three following systems of contract for the recovery of their rents :—First, There is the *Affitto in Denaro*, or contract for the payment of the rent in coin—the plan preferred by the largest class of proprietors, the administrators of church lands, of farms belonging to hospitals (which are numerous), of the estates of minors, and of communal property.

Money rents are restricted, almost exclusively, to those great irrigated farms which require the constant superintendence of highly qualified men, possessed of considerable capital. The system is rarely, if ever, adopted out of the irrigated districts. The cultivator or tenant is bound by his agreement to pay annually, in one or more payments, a fixed sum in money, which, of course, varies in every locality. He farther obliges himself to make, during the period of his tenure, certain additions to the plantations, or such other internal improvements as may be agreed upon between himself and the proprietor. There are, in addition, almost invariably, certain small payments made in kind, such as a given quantity of rice, butter, poultry, &c.; and, finally, it is usually provided that the tenant shall supply the means of transport to the proprietor, or general superintendent of the farm, when he visits it. Preparatory to the entrance of the tenant, the proprietor appoints an engineer to make a most elaborate statistical survey and valuation of the farm, with all its fixtures and stock. This document, of which I have seen many examples, is a perfect record of the condition of the farm when the tenant receives it, and is locally termed the *Consegna*. The tenant is at perfect liberty to associate an engineer of his own nomination with the party employed by the proprietor—a right which is frequently exercised. On my asking a friend, who had much experience in such matters,

how possible disputes between the engineers were adjusted, his reply was, that the system had been so long established, and was now so thoroughly understood, that disputes were very rare indeed; but that, when they did occur, the universal feeling in the profession was to give the tenant the benefit of any doubts which might arise. In the *Consegna*, the engineer describes every field separately, indicating its position, form, size, cultivation, enclosures, living and dead, the canals, sluices, bridges, roads, paths, buildings, with all their furniture and fittings. The plantations of mulberry, &c., are numbered tree by tree, and are divided into separate classes according to their quality and dimensions, each class having an established value. If, at the termination of the lease, which varies from nine to eighteen years, the plantations have decreased, the tenant is debited with the value of the difference; while, on the other hand, if they have increased, the value of this increase is placed to his credit.

When the period of the lease expires, the engineers are again summoned to frame another survey, which is termed the *Reconsegna*. In this the same minute details are entered into as in the *Consegna*. A comparison is then instituted between these two documents, and a *Bilancio*, or balance-sheet, showing the differences between them, is prepared. In this balance-sheet, every deterioration and every amelioration are exhibited, with the money-value placed upon them by the engineer; the tenant finds himself debited with the first, and credited with the second, and has either to pay to, or receive from, his landlord, certain sums, according to the results of his own administration of the farm he has held. The system works admirably. I found all parties, landlords and tenants, alike contented with it, and indeed proud of its existence among them. It maintains a very satisfactory state of

feeling between the two classes, for the tenant is encouraged to invest any capital he may have in improving the farm, being sure of receiving a just return for it, while the landlord has his property permanently benefited by the labours of an intelligent and interested man. It constantly happens that leases are renewed, term after term, sometimes for successive generations. In the upper and unirrigated parts of Lombardy, leases on money-rents are rare, being restricted to corporate or church properties. The tenant is generally, in other cases, a mere middleman, who sublets his farm in small portions, sometimes for money-rents, but generally for rents in kind, to the actual cultivators, and does not interfere at all in the management of the land. The direct renting by the landlord to the peasant cultivator, at a money-rent, is very rare indeed, although the system has been partially introduced, and is, I believe, becoming slowly extended.

The second kind of lease is termed the *Affitto a Mezzadria,* which literally implies the division of the products of the farm in exactly equal shares between the proprietor and tenant, though in practice the expression is used whatever the proportion between the shares may be—and this varies considerably in different localities, and according to special circumstances. To give an idea of the usual terms of a lease *a mezzadria,* I may mention briefly that the proprietor is bound to deliver over the farm to the tenant in an efficient state for culture, and to carry on at his own expense certain of the more important operations—as the pruning of the trees, the new plantations, the breaking up of uncultivated lands. The cultivator, on the other hand, in addition to performing the whole labour of the farm, undertakes to pay the half of the public burdens, which in farms on money leases are usually paid by the proprietor, to supply half of the wood

required for the vineyards, half of the silk-worm seed, to pay a certain rent for his dwelling-house, and to supply some small quantities of straw, &c., for the use of the proprietor. He obliges himself also to give his labour, when required, at a rate fixed in the contract. The cattle being usually the property of the tenant, he receives the whole of their produce, and the manure of the stables. The produce of the kitchen-garden and poultry-yard belongs also to the cultivator; the woods and the meadows, of which latter the extent is very limited in Upper Lombardy, being reserved to the proprietor. Finally, the cultivator is bound to deliver the whole of the other products of the farm into the granaries of the proprietor, receiving credit for the half of their value, or whatever different proportion may have been agreed upon.

It will be seen from the above sketch that the terms of the lease *a mezzadria* become very complicated; and in practice they are found to lead to frequent disagreements between the proprietors and the cultivators. These inconveniences have suggested a third kind of lease, which is termed *Affitto a Grano*, and by which the cultivator is bound to deliver into the granaries of the proprietor a fixed quantity of wheat, varying from fourteen to twenty bushels for each acre under cultivation, all the other products of the soil remaining at his disposal. The produce of the plantations, whether of vines or mulberries, belongs to the proprietor, who gives the cultivator credit for half their value; and the minor arrangements are generally the same as in the *affitto a mezzadria.* The simplicity introduced by restricting the payment in kind to a single species of grain is found advantageous in practice, though it limits the freedom of the cultivator in his work, by compelling him always, and under all circumstances, to sow a large proportion of his land in wheat

wherewith to pay his rent. It generally happens that at least two-thirds of the farm are under wheat, while from the remaining third he is obliged to raise the Indian corn and other products which are required for the support of his family.

The three kinds of lease just described are all of which I have any knowledge as prevailing in Lombardy. There are, of course, throughout the country generally, many, and in Upper Lombardy a very large number of proprietors who are themselves the farmers of their own lands. To these, who farm *ad economia*, as this system is locally termed, I need not allude here further than to say that I found them generally an intelligent, independent, and manly class, and always ready to give me any information I had occasion to seek at their hands.

It will readily be understood, from intimations given in the preceding paragraphs, how important a part the engineers of Lombardy are required to take in the whole agricultural system. Not only do they design and superintend the construction of the various kinds of works, whether ordinary or hydraulic, which are required, but the whole of the details of leases, the preparation of the various documents required on the part of landlord and tenant, and advice as to the different improvements of which the land may be susceptible, are committed to or required from them. The profession is consequently one of the highest utility. The education of the young engineers is very carefully attended to, and involves four years of apprenticeship to an established engineer. Degrees, as in Piedmont, are given at the university of Pavia; and I must state, that, after having been in personal communication with a large number of the class, I formed a high estimate of their professional ability and general intelligence. The requirements of the system have called

into existence a special division of the profession, who, under the title of *Ingegneri Avvocati*, are employed in all cases involving legal questions in hydraulics. To illustrate the demand for engineers, I was informed, perhaps with some exaggeration, that in Milan alone there were not less than four hundred, while many more are of course spread abroad over the face of the country. It is probably to the constant intercourse between the farmers and a class so numerous and well educated as the engineers that the intelligence of the former, to which I have before adverted, is in some measure to be attributed.

In studying the details of what may be called agricultural engineering, I sought assistance from several valuable works. Among these, the most satisfactory was a treatise under the title of "*Nozioni Pratiche intorno alle Consegni, Riconsegne e Bilanci dei Beni Stabili*," published at Milan in 1847, by Antonio Cantalupi, a very painstaking and laborious engineer, who has given ample details on all points connected with the peculiar institutions of which he treats, and has noted the slight differences which exist between the systems adopted in the several provinces of Lombardy; for though the principles are the same in all, that strange spirit of contrariety which is so strikingly developed in Italy generally has led to a different practice in the Milanese, the Pavese, the Cremonese, Bresciana, Lodigiana, &c. I observe that, in his preface, Signor Cantalupi states the number of engineers in Milan alone to be more than five hundred; and he mentions that their system, as described in his work, has been adopted to the exclusion of all others in the irrigated districts of Piedmont. The other works on the present branch of the subject of which I procured copies were, Pezoretti, "*Cognizione Sulle Stime dei Fondi*;" Sabini, "*Sulle Stime;*" Possenti and Emissardo on the same—all

of which are to be found in Milan without difficulty. I mention them because, perhaps, there are some who might be interested in having works which are little, if at all, known in this country.

The breaking out of the unfortunate war of liberation in 1848 interrupted the progress of a work which, judging from the only volume published, promised to be the most complete account of the physical, social, and agricultural condition of Lombardy that could have been desired. The first and only volume was published at Milan in 1844, by Signor Carlo Cattaneo, under the title of "*Notizie Civili e Naturali su la Lombardia,*" and contains a most elaborate account of the climate, the natural and artificial hydrography of the country, with other details not specially connected with my subject. Each of the above questions is treated of by the parties who were known to be best acquainted with it, and I have drawn largely upon the minute and interesting details that are given by them. In connection with the same class of subjects, I have derived much assistance from a series of letters, by Signor Cattaneo, to my kind and excellent friend Captain Robert Campbell, R.N., late British consul at Milan. These letters, which are five in number, were published in 1847, under the title "*D'Alcune Institutioni Agrarie dell' alta Italia applicabili a sollievo dell' Irlanda,*" and a condensed translation of them was published as a parliamentary paper. I must confess, however, that this translation, owing to the condensation which was considered necessary, does scant justice to Signor Cattaneo's argument, and, in truth, makes it occasionally obscure. The original letters are very clear, and full of interesting information on irrigation and its relations in Northern Italy, though Signor Cattaneo's views of the Irish question are occasionally a little prejudiced. I need mention here only one work

more, which I have found useful—viz., a work entitled "*Milano e il Suo Territorio,*" in which there are some interesting agricultural and general details connected with irrigation. The work is in two large octavo volumes, and was prepared by the *Consiglio Communale*, of the city of Milan, for presentation to the members of the Sixth Italian Scientific Congress, at their meeting in 1844. The volumes are beautifully printed and illustrated, and contain some excellent matter.

On the last branch of the subject to which I need refer here—the legislation of irrigation—the literature of Lombardy contains some most valuable materials. Independently of the details given in the old statutes of Milan, the codes of the Kingdom of Italy, and the Austrian Civil Code, there is a most elaborate work, embracing the entire philosophy and practice of the subject, by Professor G. D. Romagnosi, published originally in 1788, under the title of "*Trattato della Condotta delle acque secondo le Vecchie, Intermedie e Vigenti Legislazioni dei diversi Paesi d'Italia.*" The latest edition, of which I procured a copy, was published at Florence in 1833. It has been said of this work, that it has been repeatedly translated into foreign languages, without being perfectly comprehended, even in Italy, so obscure does the style of the author occasionally become. What has thus puzzled the writer's own countrymen must, of course, be much more difficult to a foreigner; and though I have availed myself of the information which the work affords on many interesting points, there are still numerous parts of it which I have found myself unable to comprehend. There is a useful little treatise by the same distinguished writer, which, under the humble title of the "*Manuale dell' Acquaiuolo,*" or Irrigator's Guide, gives a number of valuable legal and practical details, of which I have made use as occasion

offered. It was published at Milan in 1839, and was originally given in the last volume of the author's great work on irrigation. As specially connected with the question of sanitary legislation, I have consulted a rare work by Dominico Berra, a distinguished lawyer of Milan, which is entitled "*Dei Prati del Basso Milanese detti à Marcita*," published in 1822, and in which very interesting tabular and other statements are given, illustrative of the hygienic relations of this peculiar form of irrigation, as well as of others. With the very ancient legal writers on irrigation I have not attempted to deal; but, looking to the practical object before me, of stating the general principles of this branch of the subject, for application to the Irrigation Department of India, I have found all the materials I required in the modern Italian and the French authors to whom I have already adverted.

Having spent about three weeks in Milan, during which time my employment was incessant, I left that city on the 15th of March, for a tour through the provinces, having been furnished with a circular letter from the chief of the Canal Department to his various subordinates, directing them to furnish me with all the information I might require, and to afford me every facility in seeing the various works under their charge.

Passing by Lodi to Cremona, I had an opportunity of inspecting the Canal Muzza, one of the two great channels which, deriving their waters from the Adda, irrigate the eastern portion of the tract lying between that river and the Ticino. The fertility of this district is remarkable, even in Lombardy; and the eye ranges with delight over field after field of the richest meadows, on which, when I saw them, the wild spring-flowers were just beginning to show themselves. There is not much of the picturesque in these green plains, broken and bounded by trees which

are pruned into most unseemly forms, and studded with isolated *cascine*, or farm-houses, with but few pretensions to artistic effect; but the rich productiveness that was indicated on all sides was pleasant to contemplate, and the landscape had its own special associations, which, though not free from pain, were full of interest.

In the provinces of Cremona and Mantua we come in contact with these immense works of drainage by which the surplus waters of this low-lying territory are disposed of, and with that system of river-embankment whose remote history ascends even to those strange Etruscan times, the remains of which are still occasionally found in the earthen mounds that form the channels of the streams. To the most remarkable of these embanked rivers, the Po, I devoted considerable attention, not merely because of the intrinsic interest it possessed, but farther, because in India we have rivers similarly situated, to which the same system has been applied with good and evil results strictly analogous. I was fortunate in having had constant opportunities of personal intercourse with Signor Elia Lombardini, director-general of public works in Lombardy, who, having devoted his life to the special study of the question of river-embankments, is considered the best living authority on the subject. I am indebted to the works published by him, of which he was kind enough to present me with copies, for minute details of the system adopted generally throughout the country, and particularly in the case of the Po. These I trust to be able to give hereafter.

In passing onwards towards Verona, the extent of irrigation sensibly diminishes. A few canals may still be seen, but they are small in dimensions, and carry very limited supplies of water. The region of great canals has been left behind, and the arable land, with its trellised vineyards, and its rows of mulberry trees, takes the place

of the interminable meadows of the Milanese. In the practical application, too, of water in agriculture, the provinces immediately westward of the Adige are decidedly inferior; and the kind friends at Verona and Brescia to whom I had introductions warned me to expect nothing new in the neighbouring districts. And they were right; for, even in such localities as possessed an abundant supply of water, it was neither applied nor distributed with the minute and elaborate care so remarkable in the provinces of Milan.

After resting a day or two at Verona, the most quaint and interesting of all old Italian towns, full of architectural remains, which one longed to have weeks instead of hours to examine, I turned again to the westward, and passing along the picturesque shores of the Lago di Garda, and through the strong fortress of Peschiera, I reached Brescia, where opportunities were afforded me of examining the irrigation system of this part of the country. As in the Milanese, the water is derived both from canals and *fontanili*, or springs. Of the former there are as many as twenty-eight, supplied by the Oglio, the Chiese, and the Mella rivers; but none of them are large, nor do they present any special points of professional interest. The springs are numerous, and they are applied to use for winter meadows, as in the vicinity of Milan, though in a manner much inferior. The Brescian marcite fields I found disposed in a single slope, with a supplying channel at the crest and a drainage channel at the base thereof. By necessary consequence there was much greater waste of water, and decidedly inferior produce, than in the more minutely subdivided and better-arranged fields of the Milanese. I had an excellent opportunity of comparing the two systems on the property of M. Grassini, a Brescian gentleman, to whose courtesy I was much indebted.

The irrigating water on this property was derived from a very beautiful spring, which may be quoted as an illustration of the strange way in which rights of property to water have established themselves in this country. The proprietor could not tell me how or when the right of possession was established in his family. No written record of any kind existed to prove it; but from time immemorial the spring, though situated in the middle of another estate, had belonged to the possessors of the land he held, and efforts made before the tribunals to invalidate his claims had entirely failed. He had, however, a right only to the water; to a passage for it and for his work-people along the banks; to sufficient space on each side of the channel for depositing the sand or gravel clearance; while the soil, trees, and produce of the banks belonged entirely to the proprietors of the farm on which the spring was situated.

The only recommendation possessed by the Brescian method of disposing the marcite fields in a single slope, is its being adapted to the financial condition of the district, which possesses much fewer large capitalists than the Milanese. M. Grassini informed me that the cost of preparing land for winter meadows amounted, roughly, to about £2 per acre, while in the Milanese six times this sum is no extraordinary charge. It is, however, on the dry cultivation—the cereals, vines, olives, and silk—that dependence is chiefly placed, and not on products requiring irrigation. Indeed, the only crop, besides the grass, to which this is applied is the maize, or Indian corn, from which the favourite *polenta*, the staple food of the agricultural population, is derived.

It would be ungrateful were I to leave this neighbourhood without expressing my sense of the great kindness shown me by Count Antonio Lecchi, a classical scholar

and antiquarian of merited reputation, and Signor Fillippo Ugoni, a gentleman whose long residence in England made him the most agreeable and efficient of guides.

The great scale of the canals from the Adda made it an object of interest to me to visit the works of derivation, by which their supplies are drawn from that river. From Brescia I therefore proceeded to Treviglio, and thence to Cassano, the point at which the head of the Muzza canal is established.

It was impossible to look upon the course of the Muzza Canal without having vividly recalled to my mind the canals of the Mahommedan dynasty, in North-Western India. The resemblance was complete. The same sinuosity of channel, arising from the same ignorance of the modern means of regulating the excessive slope of the country; the same irregularity in the distribution of the fall, which caused alternations of rapids with almost still water; the same rough but massive old works of various kinds; and the same general aspects, which suggested ideas rather of natural rivers than of artificial canals. Just one hundred years before the Emperor Feroze executed what is now the Western Jumna Canal, the inhabitants of the territory to the south-east of Milan united to extend the course and enlarge the channel of a small canal, which, under the name of the *Roggia Muzza*, had existed from time immemorial. In 1220 this great work was undertaken, and was prosecuted with a degree of enthusiasm which insured its early completion. The head works, which I inspected, were established close to the little town of Cassano, and consisted of an immense *barrage* or dam, of the most solid construction, faced with blocks of beautifully cut stone, and extending obliquely across the entire river bed; of a weir, equally well built, nearly eight hundred feet in width, with four escape out-

lets for regulating the supply, having a total of forty-two sluice-gates. When I visited the spot, on the 23d of March, nearly the whole supply of the Adda was entering the canal; and a noble stream it was, being about 2000 cubic feet per second. All the works here were in excellent working order; and though very roughly finished in many respects, I have no doubt that, for practical purposes, they were quite efficient. There was no regulating bridge across the canal at the head, the weir and escapes serving to dispose of flood-waters; and the bed was hard, strong, compact gravel, well calculated to resist the current.

After examining these various works, I proceeded to Trezzo, the point at which the head of the Canal Martesana is established. I found the canal-works here situated in an exquisitely beautiful gorge, through which the Adda poured its waters with great force, and in considerable volume. High, bare, mural cliffs bounded the river on both sides. On the right, the picturesque ruins of the old feudal castle of Trezzo, partially concealed under rich masses of ivy and flowering creepers, commanded the stream. On the left, a cheerful-looking little village, with church and bell-tower rising among vines, olives, and chestnut-trees, covered the gentle slope of the river-valley; while below, the clear stream, broken into masses of white foam by the rugged-looking rocks which occasionally impeded its course, flowed onward with exhilarating life and strength. An excellent pathway, cut out of the solid rock, here and there overhung by broken masses of the cliffs, whose sides were covered with drooping ferns and early spring-flowers, led to the great dam which traversed the river-bed. This dam, like those I have described as employed in Piedmont, was formed of piles, wooden frames loaded with enormous blocks of stone, all

carefully built in, and bound together as strongly as possible. A gigantic weir, about 1800 feet in length, and constructed in the most solid manner of great blocks of cut stone, is carried along the left bank of the canal, and serves for the passage of flood-waters to the Adda. For nearly five miles the bed is carried along the right bank of the river, and sustained by massive revetments, at heights varying from forty to even seventy feet above the level of the stream. At the head there is an escape, or rather a series of three escapes, close to each other, having in all twenty-two sluices. Similar escapes exist at different points in the line, and give perfect command over the supply. The same system of small gates before referred to, as used on the canals of the Vercellese, is employed here with equal facility of management, as I saw the single guardian in charge of the head works at Trezzo open and close the gates under a pressure of nearly six feet of water, without the slightest difficulty. With the ordinary supply, in time of irrigation, the height of water in the regulators, the guardian informed me, was ten feet; and even then *one* man could ordinarily manœuvre the gates without serious difficulty, excepting after floods, when a deposit of sand or gravel took place in front of them: two men were then necessary, but never more. I must mention here, that the various works on the Martesana Canal seemed to me to be very indifferently maintained: the gates of the regulators, and all the machinery connected with them, were in a very ruinous condition, and there was altogether a slovenly and unworkmanlike air of neglect to be detected everywhere.

After spending some time in examining various minor works, which require no special notice, I left Trezzo for Como, with the view of visiting those lakes, whose usual interest is restricted to their beautiful scenery and deli-

cious climate, but which possessed, for one charged with such inquiries as mine, an additional and special interest as most important elements in that hydrographical system to which Lombardy owes its rich productiveness. Looking to the manner in which this system has been developed in nature, it is certain that if the highest human skill had been permitted to deal with the materials of which it is composed, that very adjustment which we now find to exist would probably have been employed without a single material modification. The great rivers flowing from the region of perpetual snows, through channels narrowed within rocky barriers, and disposed in slopes of excessive rapidity, would have been modulated and controlled by being made to enter into still-water basins of great superficial extent and 'proportionate depth. Entering such basins as mountain-torrents, almost uncontrollable in their force, charged with the various earthy matters they had carried away during their passage through rocks or soils which could not resist their erosive power, the rivers would be made to leave them by channels of gentler and more manageable slopes; and farther, purified by having deposited those masses of silt they had brought from the interior of the mountains. Such are, in fact, the functions performed by the chain of lakes which lie at the base of the Alpine range, and into the various members of which the rivers supplying the irrigation canals of Lombardy discharge themselves before descending to the plain. It is scarcely possible to over-estimate the value of this natural arrangement—it is one for which Lombardy has constant cause to be grateful to a skill above that of man; and looking to the natural features of the country, it is perhaps not too much to say, that without it the rivers flowing directly from the mountains would as often have blighted the land by their destructive

floods as blessed it by the discharge of their fertilising waters.

Entertaining such views, I was naturally led to examine in considerable detail the influence of the lakes in their relations to irrigation, and I shall have occasion hereafter to give the results arrived at. I need only mention here that I visited Como, Varese, the Lago Maggiore, and some of the smaller sheets of water from which the minor streams issue; and that, in doing so, I was delighted scarcely more with the natural beauty than by the rich cultivation of the country through which I passed. This is no place to advert to other impressions received, by which these feelings of enjoyment were modified, and often destroyed; for rich and beautiful as the external appearance of the land undoubtedly is, not even a very superficial observer could fail to note that here, as elsewhere throughout this now ill-fated country, there were unhappiness and discontent for which no physical advantages were any adequate relief.

It was my intention to have returned to Milan by the Naviglio Grande; but finding this impossible, from the canal being temporarily closed, I was obliged to content myself with what I had already seen of this noble work, and to proceed direct to the capital from Sesto Calende—having remained a few days in Milan, during which time the whole of the plans and accounts of the Cavo Taverna, one of the largest of the private canals in Lombardy, were most kindly and liberally placed at my disposal by Count Lorenzo Taverna, of whose attention this was but one of numerous instances during my residence in Lombardy. The information thus obtained gave me a clearer idea than I ever had before of the causes to which the failure of such works, as projects of direct pecuniary benefit, is attributable. Having completed my collec-

tion of books, and despatched them to Genoa, I quitted Milan finally, and with grateful recollections of all the kindness I had received in Lombardy, on the 2d April 1851.

My route was now directed towards Pavia, along the bank of that magnificent canal which, originally projected in 1601 under the Spanish government in Lombardy, was not finally completed till 1819, on the 17th September of which year the work was inaugurated with great solemnity. During the two hundred years that elapsed between the original conception and the effective commencement of the work in 1807, under the auspices of Napoleon, all kinds of projects, and discussions, and reports, and other wearisome formalities had effect, but nothing practical was done. The immense advantages of completing the connection between the Ticino, the Adda, and the Po, and of linking the capital with each of these rivers, were so palpable that no government lost sight of them; but unfortunately some obstacle or another invariably arose to prevent their being realised. It was not till the stern will of Napoleon was brought to bear on the subject that difficulties vanished, and the work was commenced in earnest. So long as his power remained, progress was vigorous, but a temporary interruption followed the decline and fall of the Kingdom of Italy. Twelve years, however, after the commencement of the operations, the existing government completed them, and finally conferred on the country those advantages of navigation and irrigation which the line now affords. Nothing could surpass the style in which the works of the canal of Pavia are finished. There is in it, perhaps, an extravagance, a kind of luxury, which at once arrests the attention of the observer. The beautiful work of cut stone, the continuous lines of masonry

revetment, the profusion of works of art admirably executed, and the rows of carefully tended trees which line the banks, make it on the whole the most perfect work of the class to be seen in the north of Italy. I examined the whole of the works with care, and found some of them suggestive of improvements, which may, I think, be introduced with effect into our Indian system.

I have but little more to add, than to say, that after leaving Lombardy I passed again through Turin to Genoa, whence I despatched my books and plans to England, to learn subsequently that a sad misfortune befell them *en route*—the steamer in which they were having been run into by another boat, and saved from total loss with great difficulty, but with the nearly entire ruin of the cargo. My books, &c., which had cost me so much trouble in collecting, were reduced to a deplorable state from being saturated with salt water; and though they were afterwards partially restored, the mishap was very distressing.

The general impression left on my mind by my examination of the canal-works of Northern Italy, as compared with those of British India, may be expressed in a single sentence. As regards the works themselves, whether reference is had to their designs or modes of execution, I do not think the Italians are superior to ourselves; and in regard to the manner in which the efficiency of the works is maintained, they are, I must frankly say, decidedly inferior: but in the theory of distribution, in points of interior economy connected with the use of water, and in the exactitude and details of legislation, they are far in advance of us. When, however, it is borne in mind that the one system has been in full operation for six centuries, and has, during that period, had all the care of governments, and some of the

highest intellects in the country applied to aid its development, while the other has not been more than twenty-five years in actual operation, the differences above adverted to need not be wondered at. I make bold to assert, that if the same energy continues to animate, and the same intellect to guide, the progress of the system which the British government has established in India, as of late years have characterised its operations, it will not be twenty-five years more before we have our methods of distribution, application, and legislation, theoretically equal to, and perhaps in some respects practically better than, those now existing in Northern Italy.

CHAPTER III.

THE MAREMMA OF TUSCANY.

In the valleys at the base of the great Himmalayan range in North-Western India, there are tracts of country which are lost to every useful purpose, from the waters by which they are traversed being altogether uncontrolled and unregulated. The consequence has been, that these tracts, highly favoured by nature in other respects, have been transformed into great marshy pestilential wastes, tenanted only by beasts of prey, and fatal, not solely to such human beings as pass through them—for no man can dwell there permanently—but by their malarious exhalations tainting the air for considerable distances around them. The analogous position of the Maremma of Tuscany, that most interesting tract along the shores of the Mediterranean, where the old Etruscans have left in their cities and tombs so many records behind them, made me very desirous of visiting it, and of seeing the extensive works which, for so many years past, have been in progress for improving its sanitary and social condition. With this object in view, I proceeded to Florence; and having there sought and obtained the assistance of the English minister, Mr Sheil, which was afforded with all the genial and cordial warmth of his nature, I had every facility afforded me by the Tuscan

government, and was supplied, through the medium of Chevalier Manetti, director-general of the works, with introductions to the various local authorities.

While works on a smaller scale have been carried on at different points throughout the extent of the Maremma, there are two localities which have especially received the attention of the government, and where works on a great scale have been executed. The first is the Val di Chiana, or valley of the Chiana river, which, for a length of nearly sixty, and an average breadth of about three miles, had been reduced to the most frightful state of unhealthiness and depopulation by malarious influence. The other is the great lake or marsh of Castiglione, which for centuries had been a centre of miasma, whence the whole adjoining country was infected.

On consulting with M. Manetti, he informed me that in the Val di Chiana I would see only results, as the whole of the works there had been finished for some time, and with the most remarkable success, the entire valley having been restored to culture, occupied by an industrious and now healthy population, with the low marshy localities all filled up, and the waters now under perfect control; but that to see processes I must visit the second locality, or the marsh of Castiglione, where the works were still in active progress, and their influence could be traced through all its various stages.

Acting on this advice, and warned by many kind cautions to avoid exposure to the air, either before sunrise or after sunset, I started from Florence, on the 16th April, for Grosseto, the chief town of the district in which the lake of Castiglione is situated. Passing through a beautiful, richly wooded, and, in many places, admirably cultivated tract of country, I reached Grosseto on the 17th, having traversed a road which certainly surpassed

all I had ever before seen, by the bold disregard of its constructors for every principle of good engineering. It rose over every high hill, and descended into every low valley, that lay between Sienna and Grosseto; and this, too, while an excellent alignment might have been found by following the river-valleys which skirted nearly the whole route. One compensating advantage the eccentric line adopted certainly had. It gave from the high ridges some of the most lovely views I have ever beheld—generally soft and gentle in their features, but still redeemed from tameness by the bold positions of the towns on the crests of scarped hills, and the occasional occurrence of bluff cliffs in the midst of dense and beautiful forests.

As I shall have occasion hereafter to give details of the works in the vicinity of Grosseto, I content myself with sketching here, in very general and popular terms, the outlines of the processes employed for restoring the lake to useful purposes.

The Tuscan *Maremma* is held to extend from the frontier of the Roman States to a few miles beyond Leghorn. The plain stretches inland for ten or fifteen miles in breadth, and is there bounded by a low range of hills which run parallel to the sea-shore. At many parts the bounding range of hills opens out into valleys, through which flow various rivers, of which the principal are the Cecina, Cornia, Pecora, Bruna, Ombrone, and Albegna. It is to the disorganisation of these rivers that the ruin of a tract which nature has endowed with the richest of soils and the mildest of climates, with mountains rich in precious metals and abounding in mineral springs, with plains affording abundant pastures and fit for any kind of cultivation, is chiefly to be attributed. Long before the Christian era the coasts of Tuscany had earned an unfor-

tunate name as the region of pestilence and suffering; and during the dreary centuries that passed from the time when Pliny describes them as "*sane gravis et pestilens ora Tuscorum quæ per litus extenditur*," down to the days of Cosmo de' Medici, no effort was made to restore them to their original fertility. But even his exertions proved abortive, for the works he executed were far too limited in extent to meet the evil, and the colonies he planted soon perished under, or removed beyond, the influence of the deadly atmosphere. Not more happy were the efforts subsequently made by his successors of the Medicean dynasty, and it cannot be said that any real progress was made in the improvement of the Maremma until near the close of the eighteenth century, when Padre Leonardo Ximenes, an astronomer and hydraulician of the highest reputation, was charged by the reigning Grand-duke, Pietro Leopoldo, to submit a project for the drainage of the marsh of Castiglione.

The origin of the great marshes which skirt the coast of the Maremma has been variously explained. Some authorities attribute them to the depression of the level of the land along the coast, of which, however, no proofs are quoted; others, again, call to their aid submarine elevations, which are equally unsupported by any evidence of facts; currents, transporting and depositing bars of shingle and sand at the necessary localities, help a third class of speculators: but, in truth, there is no clear evidence, so far as I have been able to discover, which establishes satisfactorily the process by which the original communication between these marshy tracts and the sea has been destroyed. That such communication did exist, however, is established by several ancient charts in which it is shown; and I myself found a proof of it in the case of the Lake of Castiglione in the old map of Italy painted

on the wall of the Geographical Gallery of the Vatican,* where a broad inlet is shown connecting the lake and the sea. As such inlets became filled up, the rivers, finding no escape, spread their waters over the plain, and so produced those miasmatous tracts which now exist.

Among these, Castiglione is the largest and most important, covering nearly thirty-four square miles of surface. It has a classic interest, having been adverted to by Cicero in his oration for Milo, as containing the island seized by Clodius from Pacavius, and which now forms a little promontory called Badiola. To the eastward of the lake flows the river Ombrone, one of the largest in Tuscany, and very rich in the earthy matters it contains. To the westward are the rivers Bruna and Sovata. The former river extends to the northward, where the boundary is completed by the high-lands; while to the south the sea-coast is the limiting line. It is on the plain between the Ombrone and the lake that the town of Grosseto is situated, a position which exposes it to the full effect of the malarious emanations from the marsh.

Ximenes seems to have believed, from the works he projected and executed, that certain simple drainage lines, with an embankment of the river Ombrone, were all that the case required. Of course, under such a system, the limits of the marsh remained very obstinately as extensive as ever. In 1788, Pietro Leopoldo called to his councils

* I have recently received from Rome, through my friend Charles Christopher Black, Esq., the following short account of the map above referred to—"These maps were painted in the Vatican Gallery by order of Gregory XIII., who flourished, as the phrase is, between the years 1572 and 1585. The artist was Ignazio Danti, a Dominican monk, brother to the great painter and sculptor of that name, who did part of the ceiling. They represent Italy divided into its separate provinces, also Avignon, and other places dependent on the popes. The reverend gentleman was thought the best geographer of his time; and I have doubts if, in modern Rome, with very few exceptions, you could find any one at present half as good." I have to thank Mr Cholmondeley of Rome for the information contained in this note.

Pio Fantoni, an eminent mathematician, who more clearly apprehended the necessities of the case, and a project was submitted by him for turning the entire volume of the Ombrone into the marsh, and, by taking advantage of the very large quantity of earthy matter with which the river was always charged, to fill up the basin of the lake, by the process of what is locally termed *Colmata*, and among ourselves is known by the name of *Warping*. Circumstances interfered to prevent this plan being carried into effect at the time; and I need not dwell on the various imperfect efforts that were subsequently made during the forty years between 1788 and 1828, to complete the suggested plan. In the latter year, the present Grand-Duke, who has always taken the keenest personal interest in the improvement of the Maremma, and constantly visits the works, called upon Count Fossombroni, a very eminent Tuscan engineer, who had directed the operations in the Val di Chiana, for his opinion on the best way of perfecting the improvement of the plain of Grosseto. The result was a most elaborate memoir by Fossombroni on the subject, supporting, by reference to the admirable results obtained in the valley of the Chiana, the adoption of the system of *colmatage*, or warping, and giving his views of the details of works for making it efficient. He calculated, very erroneously however, that the entire lake would be filled up in eight years! The process has now been in daily operation for twenty-three years, and the present state of the marsh is, that of the 33¼ square miles of which it consists, 22 have been recovered, some more, some less completely; and the remaining 11¼ continue in their original condition. As the latter portion of the work will inevitably be the most tedious, I do not think there is the slightest prospect of its being finished under fifteen years from the present time; and I should say it

would very probably occupy twenty, for there is still much to be done, even over that area which is noted above as having been already recovered.

Nothing could be more simple in principle than the process of colmatage, and it is sufficiently easy to apply it on a small scale. But when the area to be elevated, and so elevated as that it should have a regular and well-defined slope towards the sea, is so vast as that of the lake of Castiglione, it will readily be understood how difficulties accumulate, and how much minute care is required in the regulation and distribution of the earth-charged rivers. In turning to use the waters of the Ombrone, two canals were constructed from that stream, furnished with all the apparatus necessary for controlling and regulating the supplies of water admitted into them. These canals were carried onward to the centre of the marsh in excavation first, and afterwards, when the levels required, within massive embankments; minor channels were carried from them in such directions as secured the gradual progress of the new deposit; and finally, when they had left behind them the whole of the precious matters they had brought from the mountains, the waters were collected again in escape lines provided for them, by which they passed to the sea. When I visited the works I saw a large volume of water, so loaded with rich yellow earth as to appear almost viscid in consistency, entering the bed of the marsh on the eastward, and leaving it again by the outlets of San Leopoldo and San Rocco on the south-west, as pure and limpid as a mountain-stream. This process is going on unwearyingly, unceasingly. The Ombrone, if it was once a curse to the district, is assuredly so no longer. It is now the willing slave of the intelligent minds which guide its efforts; and just as surely as it continues to flow, so surely shall the day come when, in

spite of all gloomy forebodings to the contrary—of which, strange to say, I heard a great many—the marsh of Castiglione will cease to exist, and its whole area will become covered, as a considerable portion of it even already is, with rich corn-fields and luxuriant pastures. On foot, or on horseback, or in boats, I traversed nearly every part of the lake, and everywhere saw proof that the process of filling up was in satisfactory progress. The works seemed to me generally efficient, though not invariably so; and I am sure that time only is required to realise all the hopes of the promoters of the operations, on which government has already expended a sum of upwards of £600,000, which will inevitably amount to three-fourths of a million sterling, at least, before all are completed. For a small government like that of Tuscany, this implies a great and meritorious effort; and there are none, I believe, even under the present unhappy state of feeling between the prince and the people, who refuse to give to the Grand-Duke all the credit he deserves for his unwearied efforts to improve this ill-fated portion of his dominions.

How far the works, in their present incomplete state, have improved the sanitary condition of the neighbourhood of Grosseto, is a question on which I found it very difficult to obtain satisfactory evidence. Everybody directly connected with the works, of course, insisted that much good had even already been done—that fevers were less frequent and less intense; but others, unconnected with the works, were by no means inclined to report so favourably. According to the latter, the earlier stages of colmatage were invariably accompanied by an increase rather than a decrease of malarious influence; and it seems, *a priori*, by no means unlikely that it should be so, for the new deposits are alternately wet and dry, according to the state of the river, and are

covered with decaying vegetable matter, which is undoubtedly mischievous. As the process advanced, however, and the new soil was permanently raised above the level of the water, cleared and consolidated, it was generally admitted that the air became better, and, on the whole, it was allowed that the climate of Grosseto was more healthy, though still far from being perfectly so, than when the operations were commenced. It is still necessary for all, except those thoroughly acclimated, to leave the place in the summer months. All government offices are transported to the adjoining high-lands in July, and do not return till September. I looked as usual to the aspect of the population for some indications of the state of the climate, and I must say that, in the month of April, it did not appear to me to be an unhealthy or degenerate one. The examples of restoration to good sanitary condition furnished in other parts of Tuscany, and in some of the adjoining territories, as in Lucca, by the employment of the same means as are now operating in the plain of Grosseto, warrant hopeful anticipations for the future; and if these are not realised quite so speedily as some would desire, it must be remembered that the evils to be remedied are the growth of twenty centuries and more, and are not to be cured all at once. That they will ultimately be cured does not, I think, admit of the shadow of a doubt; and this conviction will be sufficient, I am sure, to support and encourage the Chevalier Grandoni and his energetic associates, amid all the difficulties, physical and moral, against which they have to contend. To the gentlemen just named, the local chief of the office of the Maremma improvements, and to the various engineers with whom I was placed in relation, I have to make many acknowledgments for their constant kindness.

With the examination of the Maremma works my professional duties terminated; and having allowed myself a few holidays to see the art-treasures of Florence and Rome, I returned to England as rapidly as I could, reaching London on the 27th of May 1851.

Having now completed my Personal Narrative, and sketched in general terms the outlines of my inquiries, I proceed to give in detail the information obtained on the various relations of the Irrigation System of Northern Italy, as they came under my observation.

PART II.

HISTORICAL AND DESCRIPTIVE DETAILS OF CANALS OF IRRIGATION IN PIEDMONT AND LOMBARDY.

PART II.

HISTORICAL AND DESCRIPTIVE DETAILS OF CANALS OF IRRIGATION IN NORTHERN ITALY.

INTRODUCTORY REMARKS.

To those who have visited the plains of Northern India and Northern Italy, the comparison of the resemblances and the differences between these two great fields of artificial irrigation is at once very interesting and very instructive. In their most important natural features they are strikingly similar. Situated alike at the bases of the greatest mountain ranges on the continents to which they belong—drained alike by rivers which, flowing from regions of perpetual snow, have their volumes influenced by similar causes—possessed of slopes which, though differently distributed and arranged, are still equally well adapted to the necessities of each—belonging to the same geological epoch, and having physical structures with the same leading characteristics—it may be said of them, that they are generically the same, but specifically different. Their differences, limiting our views to physical characters, are mainly due to the facts, that, while the hydrography of Northern India is influenced by a single

mountain range, that of Northern Italy is affected by two such ranges. In the former case, accordingly, the plain stretches away to the southward of the mountains in one continuous slope, and the rivers traversing it have the same general direction. In the latter there are two systems of slope and drainage—one from the main chain of the Alps, and the other from the minor chain of the Maritime Alps and Northern Apennines. The great receiving streams, as they may be called, of Northern India, exhibit a rough parallelism in direction to their tributaries; while the one great receiving stream of Northern Italy, the Po, flows directly at right angles to its double system of feeders, occupying the line of lowest level in the valley between the ranges that limit its basin. From this peculiarity of structure has arisen one serious, and hitherto insurmountable, obstacle to the employment of the Po as a source of supply for canals of irrigation. All such canals must of necessity intersect at right angles the whole of the tributaries met with in their courses; and so great would be the difficulties and expenses thereby entailed, that up to the present time the relation of the Po to the irrigation system, so fully developed within its basin, is a purely passive one; it supplies an effective line of escape for the waters, but as yet it does nothing more. The happier topographical features of Northern India admit of both the receiving and tributary streams being laid under contribution for purposes of irrigation.

There are, perhaps, no portions of the earth's surface which, at first sight, would seem to have less of human interest than those unapproachable solitudes which form the regions of perpetual snow; and yet their relations to the prosperity of the countries adjoining them are of the closest and most valuable character. To the periodic melting of the snows it is due that, in Italy, as in India

and elsewhere, the rivers maintain that permanency of volume which is the first essential in regions where artificial irrigation is extensively employed. Where this characteristic is wanting—as, for example, on the right bank of the Po—the irrigation is invariably limited and local. No great works can be undertaken unless a perennial supply for them is secured; and when the crests of the mountains in which the rivers take their rise do not pass beyond the snow-line, their volumes decrease just at that very time—the season of heat and dryness—when water is most required. Where, therefore, summer rains do not fall to mitigate the severity of the season, it is evident that the system of irrigation, from rivers unconnected with snow-covered mountains, must be necessarily a very imperfect one.

The advantage of permanency of supply during the season of irrigation is secured most satisfactorily to the country on the left bank of the Po, as the whole of the great rivers which traverse it rise within the regions of perpetual snow. During the month of March, the influence of the increasing temperature becomes perceptible. The streams which, during winter, had shrunk to their smallest dimensions, then begin to increase in volume, and they go on augmenting during the successive summer months, slowly and steadily, until they attain their maximum in August, after which, as the temperature falls, they gradually return to their winter channels. Of course, both in winter and in summer, floods, ordinary and extraordinary, are constantly occurring; but viewed in relation to agriculture, it is the constant and unvarying influence of the solar heat on the snows that gives to the rivers flowing from them their true value.

Though the valley of the Po is politically divided between Sardinia and the Lombardo-Venetian kingdom,

it is naturally essentially one, and indivisible. But in describing the details of the system of irrigation which has been established throughout it, there are conveniences in retaining the division above adverted to; and, in view of these, it is my intention to describe, separately, the canals of Piedmont and Lombardy.

There is not much to be said on the subject of irrigation in this country during either the classic times or the dark ages. A few references to the question by writers of the Augustan era, especially the line of Virgil in the Bucolics (Ecl. III. 111), "*Claudite jam rivos pueri, sat prata biberunt;*" an inscription of Hadrian's time, commemorating the construction of an aqueduct in the vicinity of Milan; and some few scattered vestiges of dams and other works, which are attributed in a doubtful way to the times of the empire from Augustus to Theodosius—are all the records I find noted by the historians of irrigation in the valley of the Po. That the system was, to a certain extent, employed, there cannot, of course, be any doubt; but I think it most likely that water for irrigation was derived chiefly from springs, and was used to a limited extent; for, had great works like those constructed for supplying cities with water, of which so many remarkable examples remain, been also used for purposes of irrigation, we should have had traces of them left to this day, far more distinct than any we now possess. Irrigation on a large scale, and by canals fed from large rivers, never seems to have existed until comparatively modern times. As in the East, so probably in Northern Italy, springs and wells, or small streams, easily diverted from their channels, were the sources of supply; and these would, of course, leave but evanescent traces on the surface of the country. It is in France that the most ancient traces of actual canals are to be found; and one of these, constructed

it is supposed about the close of the fifth century, bears at the present day the name of Alaric II., king of the Visigoths.* In Northern Italy there are no such works so clearly identified, and it is in vain that we seek for detailed information on any one point connected with the system of irrigation which existed there. On this branch of the subject we must therefore be content to know only, that, while irrigation certainly was employed in the valley of the Po, from the remotest epoch of which we have any record, there is every reason to think that few, if any, works of magnitude were constructed, that the extent of the system was limited, and, as compared with its more modern development, of very minor importance.

* Berra quotes from Cassiodorus (Dei Prati detti á Marcita, p. 6) two very curious letters of Theodoric I., King of the Goths—one to the Senate of Rome, directing that all possible encouragement should be given to a certain Decius, who proposed to drain and restore to culture a portion of the Pontine Marshes; the other is addressed to Decius himself, and exhibits the King as a most earnest and most encouraging land-improver. He promises liberal rewards in terms of great courtesy, and says he regards the operations with the deepest interest. The same author (p. 8) quotes another letter of Theodoric's, in which orders are given for the payment of the travelling-expenses of a hydraulic engineer brought *from Africa to Rome*, to show the manner of obtaining and regulating supplies of water from rivers.

CHAPTER I.

CANALS OF IRRIGATION IN PIEDMONT.

SECTION I.*

HYDROGRAPHY—CLIMATE—SOIL—POPULATION OF THE IRRIGATED DISTRICTS OF PIEDMONT.

A NECESSARY preliminary to the detailed account of the canal system of Piedmont is a general and rapid sketch of the physical features of the country. Though irrigation is practised to a considerable extent in the valleys on the right bank of the Po, where the smaller streams, flowing from the minor chain of the Maritime Alps, are taken advantage of, yet local difficulties, arising from the extreme irregularity of the ground, and especially from the uncertainty of supply in the summer time, have hitherto prevented, and must continue to prevent, any great extension of the system in these localities.

The great irrigating district of Piedmont is, accordingly, situated on the left bank of the Po, and is comprised between the tributary rivers, the Orco and the Ticino.

* The authorities consulted in the preparation of this section are—"*Transactions of the Royal Academy of Turin;*" "*Reports of the Statistical Commission of Piedmont;*" "*Considerazioni sulle Terre Incolte del Piemonte, di A Piola;*" "*Traité des Irrigations par M. Nadault de Buffon;*" "*Notizie Civile e' Naturali su la Lombardia, di Carlo Cattaneo.*"

It embraces the provinces of Ivrea, Vercelli, Novara, Mortara, and Vigevano, all forming parts of that great alluvial plain which extends from the base of the Alps to the banks of the Po. The total superficial area of the irrigated region adverted to may be estimated at about 2500 square miles, or, approximately, 1⅗ millions of acres. This is by no means the whole superficial area which in Piedmont has been brought under the influence of irrigation more or less completely, as there are other tracts of considerable extent which, under favourable local circumstances, have been able to avail themselves of the waters from the adjoining streams. But these latter localities are isolated from the great irrigated region to which reference is at present restricted, and they need not now be specially noticed.

The irrigated plain slopes from the base of the mountains towards the Po, at inclinations which necessarily vary exceedingly in different localities, but which range in general terms from about five to as much as twelve feet per mile. The consequence of this rapid fall is, that the velocity of the rivers which traverse the plain in a general direction from north-east to south-west is considerable. Their beds, however, are invariably strong and compact, composed of gravel and boulders, and well calculated to withstand all erosive action.

The principal streams forming the hydrographic system of the irrigated district are (commencing from the westward, and travelling to the east), the Orco, the Dora-Baltea, the Sesia, the Agogna, the Terdoppio, and the Ticino. From all of these rivers, and from their tributaries—the Chiesella, which joins the Dora, and the Elvo and Cerio, which join the Sesia—supplies of water are drawn for agricultural purposes ; so that the tracts of country between them are literally covered in every

direction by artificial channels of various dimensions. The region of the Alps, whence they all flow, includes the loftiest peaks of the chain ; and, among others, Mont Blanc, Monte Rosa, Cervino, &c., all crowned with perpetual snow, and hence insuring, during summer, an abundant supply to the rivers.

One marked deficiency, however, characterises the hydrography of Piedmont as compared with that of Lombardy—it has no great lakes to regulate and purify its streams. With the single exception of the Ticino, all the other rivers flow directly from the mountains. Their fluctuations of volume are consequently excessive. The floods, to which in spring and autumn they are subject, are in no way modified by the useful intervention of the basins which receive the Lombardian rivers; and further, they are found to bring with them, from the mountains, large quantities of fine grey sand, which, if deposited in the beds of the canals, is a constant source of embarrassment and expense, or, if spread over the soil, is injurious to its productive powers. With these admitted imperfections, however, the hydrography of Piedmont is still admirably adapted for purposes of irrigation — a fact best proved by a glance at the map, which will show the extent to which it has ministered to these ends.

No mention is made of the Po among the irrigating rivers of Piedmont. It is not impracticable to employ the waters of that river for irrigation in Piedmont; and my excellent friend, M. Charles Noé, has prepared and submitted to government a project for a canal of the Po, rivalling in dimensions the great works of Lombardy; but as yet no measures have been adopted to carry it into execution, and, as I formerly mentioned, the Po is at present simply the drainage line of the country through which it flows.

The following tabular statement will give the reader a definite idea of the areas of the basins and the discharges of the irrigating rivers of Piedmont. It cannot, of course, be considered rigidly exact, but I believe it to be a tolerably close approximation to the truth. I have included the Stura and the Dora-Repaira, though the irrigation from them is very limited, and also the main tributaries on the right bank of the Po.

AREAS of the BASINS in Square Miles, and DISCHARGES in Cubic Feet per Second, of the IRRIGATING RIVERS of PIEDMONT, Affluents of the Po.

LEFT BANK.	Area of Basin, square miles.	Discharge cubic feet per second.
1. Dora-Repaira, ...	473	1,995
2. Stura, ...	369	1,400
3. Orco, ...	482	1,610
4. Dora-Baltea, ...	1662	7,525
5. Sesia, ...	1123	2,730
6. Agogna and Terdoppio, .	842	700
7. Ticino, ...	2705	11,270
	7656	27,230

RIGHT BANK.	Area of Basin, square miles.	Discharge cubic feet per second.
1. Gurone, Staffora, Tidone, &c.,	721	875
2. Scrivia, ...	420	735
3. Tanaro, ...	3070	4655
	4211	6265

Whence it appears that in the irrigated districts on the left of the Po there is a total volume of water equal to a little more than 27,000 cubic feet per second discharged by the rivers which traverse it. The precise portion of this which is actually employed in irrigation will be indicated hereafter—for it is scarcely necessary to remark, that it is a portion only which can be so employed—and in

the case of the largest of all the rivers specified, the Ticino, the district of the Milanese carries off the lion's share of its contents. The table will, however, give some distinct idea of the rich abundance with which nature has provided for the agricultural necessities of the district under notice.

To enable me to judge of the climate of Piedmont in its relations to irrigation, I examined in detail the meteorological observations made at the observatory of Turin, taking a series extending over ten years, which appeared to me sufficient for all practical purposes. It is not necessary to give here all the details of these tables, but I will simply state the general results they afford.

The irrigating season may be considered to commence in March, and to terminate in September. The elements of climate which are most intimately connected with the process of irrigation are the temperature and moisture of the atmosphere. The discussion of the ten years' observations gives, accordingly, the following average results in relation to these points during the season of irrigation, as above limited :—

TABLE showing the TEMPERATURE, RAIN-FALL, and WEATHER during the SEASON of IRRIGATION in PIEDMONT.

	Mean Temp.	Rain-fall.	Clear days.	Cloudy.	Rainy.
	Fahr.	Inches.			
March,	45·09	2·84	13	10	8
April,	51·95	4·14	9	10	11
May,	61·49	6·33	8	9	14
June,	74·84	3·71	9	11	10
July,	74·63	3·37	12	10	9
August,	71·53	4·80	11	10	10
September,	62·91	3·37	12	9	9

The months when water is in greatest demand are May, June, July, and August, which show a mean temperature of about 72° Fahr., and an ordinary maximum of 85° 32′.

During the same months, however, the thermometer, exposed to the sun, rises to a mean height of 91° 97′—a fact of considerable interest as connected with irrigation, which is essentially necessary to temper a heat so excessive.

The average annual fall of rain, as deduced from ten years' observation, is very nearly 37 inches, of which the large proportion of 28½ inches falls during the seven irrigating months. This quantity is divided with considerable regularity over 71 rainy days, giving a daily fall of about $\frac{4}{10}$ of an inch. The perfectly clear or partially cloudy days, taken together, are just double the number of those on which rain falls; and though this proportion is not quite so favourable as in Lombardy, still it is well adapted for a country provided with means of irrigation, as there is sunshine and heat sufficient to mature the products, such as rice, Indian corn, &c., which demand these as well as the employment of water to insure their perfection. As regards the sole kind of irrigation practised during the winter months—namely, marcite or winter-meadows—its success appears to depend on causes quite unconnected with climate. The high temperature of the water employed, and the peculiar disposition of the soil, with its results on the irrigating stream, seem to be the chief points on which this species of cultivation is founded. I have been informed that snow does not lie on the marcite fields; nor is the thin veil of water, constantly moving over their surfaces, liable to freeze, except during the severest frosts.

The soil of the irrigated plain presents all those varieties found in ordinary alluvial deposits. Even within restricted limits the changes exhibited are considerable, passing from light sand to dense clay, and in many places showing much gravel mixed with the earthy constituents of the land. Except in low-lying spots, where deficiency

of drainage has led to the gradual formation of marshy deposits, the soil is generally light, but when water is employed, fertile to a high degree. The heavy argillaceous soils are devoted with special success to rice cultivation. On the lighter all the cereals—Indian corn, and varieties of green crops—are reared. There is no part of the irrigated district which has shown so remarkably the influence of irrigation in improving its soils as the ancient Lumellina, which comprises the modern districts of Mortara and Vigevano. Prior to the construction of those great canals which now traverse these provinces, all authorities agree in picturing their condition as deplorable in the extreme. Their soil—arid when light and sandy, and when heavy, retaining the water, and so forming pestilential marshes—remained almost waste; no regular culture could be established; the population was scanty and impoverished; and, with the unhealthy state of agriculture, internal industry and external commerce had their usual close sympathy. Nothing could be more striking than the contrast between the Lumellina unirrigated and the same district irrigated. Now it rivals the Milanese in its rich productiveness; it is one of the most densely populated regions in Europe; its soils have received just the element they wanted to call forth their inherent powers; and instead of arid wastes or extensive marshes, corn-fields, green meadows, or rice grounds, cover the face of the country.

The population of the irrigated plain amounts to very nearly one million of souls. A very elaborate report on the population of the kingdom of Sardinia has been published by the Royal Statistical Commission; and I have carefully examined this, with a view to tracing the influence of irrigation on the numbers of the people—an influence which exhibits itself in the Statistics of Irrigation

in India in the most remarkable manner. In Piedmont, however, it is far less marked. Neither in the ratio of population to superficial area, nor in that of periodical increase, does irrigation appear to have the same effect there as in India, or indeed in Lombardy. There are high-lying districts where dry cultivation only prevails, which show even a greater number of inhabitants to each square mile of surface than in the special region of irrigation. The most densely populated district of Piedmont, with the single exception of Genoa, which is affected by the city population, is the province of Asti, famous for its wines, which shows 352·5 per square mile, and exceeds even the district of the capital, which has only 340·6 per square mile. The following short statement will illustrate this point sufficiently for my present purpose. I request it may be noted that, in some of the districts characterised as unirrigated, limited and local irrigation from mountain streams may, and does, exist; but its influence is very slight indeed, and may safely be neglected.

COMPARATIVE STATEMENT of POPULATION in IRRIGATED and UNIRRIGATED DISTRICTS in PIEDMONT.

Irrigated.	Population per square mile.	Unirrigated.	Population per square mile.
1. Turin, . .	340·6	1. Savoy, . .	235·7
2. Ivrea, . .	286	2. Biella, . .	343·2
3. Vercelli, . .	225	3. Asti, . .	352·5
4. Novara, . .	227·5	4. Casale, . .	330
5. Mortara, . .	267·5	5. Voghera, . .	305
	1346·6		1566·4
Average of irrigated districts, . .	269·5	Average of unirrigated districts,	313·26

It will be seen that the superiority of the unirrigated districts, as shown above, is by no means inconsiderable,

and is in striking contrast to the results in India, where we find irrigating districts have a population per square mile varying from one to two-fifths greater than in unirrigated ones. I shall have occasion to advert again to this subject in reference to similar phenomena in Lombardy, and I may then endeavour to show why it is that regions of dry cultivation in Northern Italy support a larger population in proportion to their superficial area than the others.

In the progressive increase of the population within determinate periods, there is a considerable advantage in favour of the irrigated districts, as will be seen in the following brief statement :—

STATEMENT of PROGRESSIVE INCREASE of POPULATION in certain IRRIGATED and UNIRRIGATED Districts of PIEDMONT between 1819 and 1832 (the latest dates as yet available for reference).

Irrigated.	Increase in 20 years.	Unirrigated.	Increase in 20 years.
1. Turin, . .	0.20	1. Savoy, . .	0.22
2. Ivrea, . .	0.18	2. Biella, . .	0.21
3. Vercelli, . .	0.41	3. Asti, . .	0.19
4. Novara, . .	0.29	4. Casale, . .	0.11
5. Mortara, . .	0.31	5. Voghera, . .	0.14
	1.39		0.87
Average of increase in irrigated districts, . .	0.278	Average of increase in unirrigated districts, . .	0.174

I believe the last census, which has not yet, to my knowledge, been published, would indicate a continuance of the superior ratio of increase in the irrigated districts ; and this is satisfactory, as showing the improvement of the material condition of the population.

Among the tables given by the Statistical Commission is one showing the distribution of the population accord-

ing to their domestic state. Thinking that some indication of the relative conditions of the people in irrigated and unirrigated districts might be obtained from comparing the number of marriages in each, I reduced this Table ; and whatever inference the results may justify is again in favour, though very slightly, of the unirrigated tracts, as the following statement shows :—

STATEMENT showing the proportion of MARRIED and UNMARRIED in the POPULATION of certain IRRIGATED and UNIRRIGATED Districts of PIEDMONT.

Irrigated.	Married to unmarried.	Unirrigated.	Married to unmarried.
1. Turin,	1 to 1.77	1. Savoy,	1 to 1.98
2. Ivrea,	1 to 1.86	2. Biella,	1 to 1.80
3. Vercelli,	1 to 1.53	3. Asti,	1 to 1.47
4. Novara,	1 to 1.70	4. Casale,	1 to 1.37
5. Mortara,	1 to 1.50	5. Voghera,	1 to 1.30
	5 to 8.36		5 to 7.92
Average of irrigated districts,	1 to 1.67	Average of unirrigated districts,	1 to 1.58

I will add only one other illustration of the state of the population in the two classes of districts under notice; and this will show that, while the inhabitants of the unirrigated provinces marry in greater numbers than in the irrigated ones, their marriages are also more prolific.

STATEMENT showing the NUMBER of INDIVIDUALS to a FAMILY in certain IRRIGATED and UNIRRIGATED Districts of PIEDMONT.

Irrigated.	Number to each family.	Unirrigated.	Number to each family.
1. Turin, . .	4.59	1. Savoy, . .	5·29
2. Ivrea, . .	4·98	2. Biella, . .	5·10
3. Vercelli, . .	4·81	3. Asti, . .	4·77
4. Novara, . .	5·12	4. Casale, . .	4·76
5. Mortara, . .	4·87	5. Voghera, . .	5·13
	24·37		25·05
Average of irrigated districts, .	4·87	Average of unirrigated districts,	5·01

When I commenced the discussion of the population returns of Piedmont, it was with the belief, and I may add the hope, that the results would furnish arguments in favour of irrigation. It has not been so ; for in the ratios of number to area, of married to unmarried, and of families to families, the advantage is on the side of the unirrigated districts. The progressive increase of population, in which a superiority is observable throughout the irrigated provinces, must, I presume, be attributed to immigration—to the permanent settlement of a portion of that migratory population which year by year visits the irrigating districts during harvest-time. With fewer and less prolific marriages than in the other localities, this seems to be the only way of explaining the difference above adverted to. But though *relatively* the argument in favour of irrigation may fail, it is only necessary to contrast the present condition of the provinces where it now exists, with their past state, to feel that *absolutely* it is scarcely possible to exaggerate the beneficial influence it has had.

SECTION II.

GENERAL HISTORICAL SUMMARY OF THE ORIGIN AND PROGRESS OF IRRIGATION IN PIEDMONT.

There are two methods by which the facts to be subsequently given may be grouped. First, according to their succession in time, or in chronological order; or second, according to their succession in position, or in topographical order. Now, as many of the canals to be described were executed in different provinces at the same time, or in the same provinces at different times, it is evident that a rigid adherence to chronological order would lead us to move over the face of the country in a somewhat confused and unsatisfactory manner, and that an imperfect picture of the existing distribution of the irrigation system must be the inevitable result. It therefore appears to me to be the preferable plan to neglect the strict order of time, and to describe the various canals of each province according to their topographical position. By thus commencing from the western, and travelling regularly to the eastern limit of the irrigated plain, a clearer view of its present state will be obtained than the first-mentioned plan could give. I propose, therefore, describing in succession the canals of the Orco, the Dora-Baltea, the Sesia, the Agogna, the Terdoppio, and the Ticino, without special reference to the epochs of their original construction.

It may still, however, be interesting to sketch the historical progress of irrigation in Piedmont; and as, fortunately, this can be done in a few sentences, it will not detain us long to give it here.

The date of the most ancient among the existing canals of Piedmont ascends to the commencement of the fourteenth century—the same period, I may note in passing, at which the great canal-maker of India, the Emperor Feroze, was employed in the construction of the work which still bears his name. The Roggia, or canal Gattinara, derived from the Sesia, is a contemporary of the canal of Feroze, executed about the year 1320. In the course of the same century, but nearer to its close, the canals Busca and Santirana, deriving their supply also from the Sesia, were constructed. The canal Langosco was derived about the middle of the fourteenth century from the river Ticino, and completes the list of the works attributable to this period.

During the succeeding, or fifteenth century, considerable activity prevailed. In 1400, Duke John of Montferrat constructed the Canal del Rotto, drawing its supply from the Dora-Baltea, which then for the first time takes its place as a member of the Irrigation System of Piedmont. In 1468 the canal of Ivrea was drawn from the Dora-Baltea; but owing to certain difficulties of maintenance it was abandoned, after having flowed for about ninety years. Restored in the succeeding century, or about 1651, it has continued its useful services without interruption from that time to the present day. To the fifteenth century also belong the canals of the Commune of Gattinara, Mora, and Sforzesca. The only important work which dates from the sixteenth century is the canal of Caluso, a derivative from the river Orco. The restoration of the canal of Ivrea, formerly adverted to, is the sole work which I can trace to the seventeenth century. To the eighteenth belongs the canal of Cigliano, with some of its branches; and to the nineteenth, the canal of Charles Albert, which, however, I am sorry to add, has

proved, so far as its influence on irrigation is concerned, a very unsatisfactory work.

The most active period in the course of the five centuries during which the present canal system of Piedmont has existed, was the feudal eras of the fourteenth and fifteenth centuries. The works then constructed were the results almost equally of the energy of the state and the enterprise of individual proprietors. It was under the dukes of Milan that the great canals of the Lumellina were made, as it was not until 1736 that the provinces of Novara and Mortara were separated from the Milanese. It was under the auspices of the princes of the house of Savoy that the canals of the Orco and the Dora-Baltea were executed, sometimes directly by the government, but most frequently under patents from the sovereign to different noble proprietors.

For a long series of years the system of canals thus called into existence was administered in a very rude and imperfect way. No surveillance was exercised over the distribution of the waters. Every man supplied his own wants very much according to his own wishes, for the times were troubled, and internal commotion and external war occupied the attention of the government too much to admit of much care being given to the regulation of public works. Very shortly after the construction of the canal of Ivrea, the first faint indication of some method in the distribution of the water is discernible; and under the reign of Philibert I., duke of Savoy, in the year 1474, we find a rude plan of regulated outlet prescribed for that canal. By slow and halting steps, modifications of this—to be described hereafter—were gradually introduced, until we arrive at the metrical module of the present day.

The canals adverted to in this sketch are only the

leading arteries, as it were, of the system. During the time included between the commencement of the fourteenth and the middle of the nineteenth centuries, an immense number of smaller works, dependent on the great lines, were constructed. In fact, the importance of irrigation would naturally be recognised at once, and the execution of the works required to give it full effect would be limited only by the means of the people. The extent to which these have been employed is best shown by a glance at the map, which exhibits an almost countless number of channels, of which the special history, however, would present literally nothing whatever to interest us.

It was from the eastward—from the rich plains of Lombardy—that the spirit of improvement spread. Developed first in the Lumellina as a part of the ancient Milanese, it crossed the Sesia in course of time, and finally worked its way onward to the banks of the Orco, where, in its great features, it may be said to have stopped, as farther to the westward but little has been done. Nearly five hundred and fifty years have been required to organise the existing canal system of Piedmont—to change its once arid plains or dreary marshes into sheets of cultivation. I would "point the moral" it indicates for us, who are only beginning our work, as it were; and would say, that we may have fair hopes and cheerful hearts in sight of what we have already done in a twentieth part of this time.

SECTION III.

CANALS OF THE RIVERS DORA-REPAIRA, STURA, AND ORCO.

The canals from the Dora-Repaira, and the Stura, in the province of Turin, are so small that I had some doubt as to the necessity for noticing them at all. It may, however, be as well to do so briefly. Those derived from the Dora are designed chiefly for the use of the royal domain, and their waters are employed either as the moving power in the royal manufactories of different kinds, or (though to a very limited extent) in irrigation.

The canal of the Veneria Reale, which is the most important, was constructed in 1750. It carries a volume of water, in summer time, amounting to about seventy cubic feet per second. Its length from its head near Pianezza is about eight miles, and during its course it irrigates about 500 acres of meadow land. It has twenty-one small bridges and aqueducts, the property of government, and two belonging to private parties. The charge for the use of water from it for irrigation ranges from nearly 2s. to 2s. 6d. per acre; and it is used as the motive force for machinery in two leather works, five silk manufactories, and three corn-mills.

The canal of the Royal Park, with its small subsidiary branches, is appropriated to the exclusive use of the government paper-mills, tobacco manufactories, &c. The main canal is about two and a half miles in length, with a discharge in summer time of about 200 cubic feet per second. The subsidiary channel is about one mile in length, with a volume of ninety cubic feet per second.

The extent of irrigated land is, however, only 250 acres, or thereabouts, and the chief use of the works is for mechanical purposes. The subsidiary canal preceded the main line in its construction, having been excavated in 1655, while the latter dates from 1775.

The principal canal from the Stura is the canal of Fiano, which is derived from that river at a place called Cafasse, near Lanzo. It has a length of ten miles, and a volume of forty-eight cubic feet per second in summer, with half that quantity in winter. It irrigates 950 acres, and drives sundry corn and rice mills in its course through the districts of Cafasse, Fiano, and Veneria. The date of its construction was 1726; it was commenced by the community of Fiano, and completed by the government. Its annual revenue is no more than about £40, very nearly the whole of which sum is absorbed in keeping it in working order. The low revenue is attributable to the fact, that numerous gratuitous concessions of water have been made from it to different parties.

About 1740, a second canal, for the use of the Veneria Reale, was derived from the Stura at Robassomero. Its length is nearly five miles, its summer volume twelve, and its winter volume eight cubic feet per second. It irrigates about 200 acres belonging to farms of the royal domain, and supplies the domestic wants of the establishments.

There is a small subterranean channel, about three miles in length, supplied by springs in the valley of the Stura, which has been constructed for the use of the government paper-manufactory in the Royal Park. It was executed in 1790, and carries only about half a cubic foot per second.

The first work of real importance, as connected with

the irrigation system of Piedmont, is the canal of Caluso, derived from the left bank of the river Orco, near a place called Castellamonte. The history of this canal has been given in great detail by M. Michela,* Engineer-Inspector of the finance department; and from his work I have condensed the following summary.

The deficiency of water, and the depression of the population consequent thereupon, throughout the districts of Castellamonte, Bajro, and Agliè, induced the Marshal Carlo Brisach, feudal lord of Caluso, to project, in the year 1556, a canal from the Orco, having its derivation or head near Castellamonte. Henry II. of France, to whom the right then appertained, having granted the necessary permission to obtain a supply from the river, and to carry the channel through the districts of Castellamonte, Bajro, and Agliè, and like authority having been procured to traverse the districts of San Giorgio, Montalenghe, Orco, and Barone, from the Duke of Montferrat, the marshal completed his work in 1560.

So sensible were the proprietors of the communes to be traversed by the projected canal, of the benefits which would result to them from the speedy execution of the work, that they voluntarily undertook to recompense, at their own cost, all parties who had to cede their land for the canal bed. When such a spirit prevailed, the works naturally advanced with vigour and success; and within four years from their commencement the canal was ready to supply irrigation to the fields, and motive power to the various mills which had been constructed upon it.

The Duke of Savoy, Emanuel Philibert, having at this time obtained possession of the country traversed by the canal, confirmed to the Marshal Brisach the concession formerly made to him, by a patent under date the 18th

* *Cenno Istorico e Statistico sul Regio Canale di Caluso.* Torino, 1844.

March 1560, protecting the grant by sundry penal enactments against all infringements of it.

At the close of 1560 the Marshal Brisach disposed of the fief and the canal of Caluso to Anna di Alanzon, marchioness of Montferrat; and the Duke of Savoy again confirmed all the concessions and privileges connected with the latter, by patents under dates the 30th of January 1562 and the 18th of August 1563.

Sundry other proprietors subsequently possessed the canal of Caluso, and in 1593 it became vested in Vicenzo, duke of Mantua, who exchanged the fief for that of Strovi with the Counts Manlio and Carlo Guglielmo Valperga. All the rights and privileges connected with the fief and the canal were confirmed to these noblemen by Carlo Emanuel I., duke of Savoy, by patent dated 20th December 1593, in which it was stipulated that all fines for breaches of the regulations should be divided in the proportion of one-third to each, between the government, the proprietors, and the informers; and that, farther, a sum of two thousand ducats should be paid by the Counts Valperga in recognition of the sovereign dominion of the Duke of Savoy. From this time forward the ducal government, finding it profitable, began to interest itself in the canal of Caluso.

From 1593 down to 1729 there were numerous successions to the fief of Caluso, and ultimately lawsuits of the most complicated character arose in relation to it. On the 31st October of the latter year, the Chamber of Accounts finally decided that all feudal rights belonged to the Marchese d'Albarey; but it declared the concessions regarding the canal of Caluso invalid, transferring to the royal domain the right to the water on repayment by the government of the two thousand ducats previously paid in terms of the patent of the 20th December 1593; but

reserving to the feudal lord the power of using the water until such repayment was made.

As it was not convenient to the government to repay the sum just mentioned, the Marchese d'Albarey remained in undisturbed possession of the canal for sixteen years from the date of this decision. In 1746, however, the administration of the domain having proposed to repay the necessary sum, the proprietor petitioned Carlo Emanuel III. to continue to him the right of drawing the requisite supply of water for the canal from the Orco, offering to pay for this right an annual sum, amounting to one-sixth of the returns of the canal. On the report of a royal commission, appointed to examine the proposal, the king sanctioned the request made, and a provisional concession was granted, to endure only while the annual return was paid, but to cease at once if that should fail.

While this grand series of litigation was in progress between the proprietor and the state, there was a minor series, quite as actively pursued, between the proprietor and certain of the consumers of the water of the canal, chiefly with the community of Caluso. After nearly a quarter of a century of constant squabbling, it seems suddenly to have occurred to the communal authorities of Caluso that they were, in point of fact, contending with a shadow; that the proprietor was no real proprietor at all; that his grant of water was revocable at the will of the sovereign; and that they had better carry their case at once to the latter, if they wished to have it finally adjusted. This they accordingly did, telling the king that to leave the canal in the hands of a private individual was to injure the country greatly; that they were forced to pay extravagant sums for the use of the water, even as much as from five to six *lire* for every hour (truly a great burden!) and that there were many communities who

were prepared, under a more reasonable system, to make all sorts of improvements, and greatly to extend their cultivation. They therefore prayed that the concession to the proprietor might be abolished, and the administration of the whole work undertaken by the finance department.

I have no doubt the opportunity of acquiring a profitable property in a legitimate kind of way was eagerly enough taken advantage of, for a royal commission entirely agreed with the recusant communities, and stating that San Giorgio would bring under cultivation a waste of nearly 400 acres, if it could have irrigation, Mazzé another of 700 acres, Rondezzone a third of 350 acres, Chevasso a fourth of 500 acres, and so on, it recommended an immediate compliance with the request made. So by a convention with the Conte Valperga Masino, feudatory of Caluso, under date the 18th of March 1760, the government became the proprietor of the canal and all its works. The terms of the convention are not specified, but we will hope that fair compensation was made to the feudatory on the extinction of rights possessed by his family for upwards of two hundred years. However this may have been, it is unquestionable that the transfer of the canal to the state was eminently beneficial to the community generally, as far more than the anticipated benefits were early derived from it.

Carlo Emanuel III. seems to have interested himself much in the improvement of the canal of Caluso, and to have devoted to this object sums which, at that period, were very large. To shorten the winding course of the channel in the vicinity of San Giorgio, two tunnels—one nearly 2300, the other 2400 feet in length, having a common section of about 11 feet in width, and 27 in height, from the flooring to the crown of the arch—were proposed. Notwithstanding many objections and much

serious difficulty of execution, these works were completed in 1764, by the architect Bays, and remain as a very remarkable instance of skill and energy for the time at which they were constructed. Various other improvements were carried into effect. The king having established a royal stud near Chevasso, the canal was prolonged to the spot; the head works were moved farther up the river to a more convenient point, and established of such dimensions as to be capable of conveying about 350 cubic feet of water per second. Regulators were constructed for the due division of the waters among the consumers. Well-considered police regulations were introduced, and the general system of the distribution of the water was made to assume form and method.

It is to the engineer Contini that Piedmont is indebted for the first introduction into the irrigation system of the country of a module for the measurement of the water. The rude method before employed was to grant concessions in terms of so many *ruote d'acqua* (literally, wheels of water), which were considered to mean the quantities necessary for driving a water-wheel,—a very vague and indefinite standard. The details of the *Oncia di Caluso*, introduced in 1786 by Contini, will be given hereafter. It is only necessary to say here, that it is the quantity of water which passes through an opening four and a half inches wide by six inches high, under a constant head pressure of three inches. The volume thus discharged is equal to very nearly 0.85 cubic feet per second in English measure. For a great many years afterwards the *Oncia di Caluso*, or *di Contini*, as it is sometimes called, was employed in regulating all grants of water, and was certainly most useful, though it had some palpable defects, which will be noticed in another place. In 1801, modifications of the module of Contini were introduced (and by

no means judiciously) by Ignazio Michellotti, a very eminent mathematician and hydraulic engineer; but these did not meet with general approval, and soon fell into abeyance. Both forms are now displaced by the legal module established by the code of Charles Albert, according to which all property in water is at present defined.

At the beginning of the present century, it was calculated that the discharge of the canal of Caluso was equal to 366.26 cubic feet per second—sufficient for the irrigation of nearly 18,000 acres, if the supply had been carefully economised; but, owing to deficiencies in this respect, the actual extent of irrigation did not exceed 15,000 acres. In the tract irrigated by the canal of Caluso, it is held that irrigated land returns a rent of nearly twelve shillings an acre in excess of that derived from unirrigated land. Hence the benefit conferred on agriculture by the canal in this comparatively small district amounts to about £9000 per annum. The returns from mills of various kinds raise this to nearly £10,000; so that the government and the community have good reason to congratulate themselves on the results of the administration of the works.

Near the close of the last century, the King Vittorio Amadeo III. amused himself, and thought to benefit his kingdom, by the introduction of the Merino sheep. The establishment of the *mandria*, or stud, formerly adverted to, was made the site of this experiment, which, however, does not seem to have proved a very successful one. In 1801 a company was formed, consisting of nobles, for prosecuting the royal project; and they rented for this purpose the stud-lands on the canal of Caluso, on condition that they entered into occupation with 2000 sheep, and bound themselves to raise the number to 6000 within four years. To the same society the whole of the canal

of Caluso was rented for twenty years, at a money-rent of about £320 per annum, with obligation to make all necessary repairs and improvements at their own expense.

The value of the canal and the improvements of its works have been in steady and gradual progress from the time when it was held by the Pastoral Society up to the present day. It has been, on the whole, a successful and useful undertaking, and I hope the sketch of its history now given may not be altogether uninteresting.

It remains to give a general description of the works of the canal.

The canal of Caluso is derived from the left bank of the Orco, near the point at which that river receives the tributary streams of Piova and Rivatorto, and in the immediate vicinity of the town of Spinetto, in the district of Castellamonte. It terminates in the royal domain of the Mandria of Chevasso, after a course of nearly twenty English miles, traversing and fertilising the nine districts of Castellamonte, Bajro, Agliè, San Giorgio, Montalenghe, Orfo, Barone, Caluso, and Mazzè. Its mean breadth at bottom is 18 feet, its breadth at the surface of the water 26 feet, its mean depth below the level of the country $6\frac{1}{2}$ feet, and the average depth of water about $3\frac{1}{2}$ feet. The area occupied by the channel and banks is estimated from measurements, made along the entire length of the canal, as equal to $54\frac{1}{4}$ acres.

In the distribution of the slope, the original constructor of the canal seems merely to have adopted the natural fall of the ground through which the work was carried. Extreme irregularity in the declivity of the channel has been the natural consequence, and it is to the compact nature of the soil only that the maintenance of the bed in working order is due. The fall is thus distributed :—

	Feet.
Fall from the level of the sill of the dam at the head to that of the flooring of the bridge at the Cascina Savonara, .	404.08
Falls for the mills of Bajro and Caluso, falls of Cassone, and of the three distributing edifices of Castellamonte, Arré, and of the Regia Mandria, amounting in all to . . .	66.00
Fall of the channel, . .	338.08

From which it appears that the canal has a general slope of very nearly 17 feet per mile! This is, at least, ten times more than it ought to have; and the canal of Caluso is certainly not to be quoted as an example for imitation, as the loss of power for industrial purposes alone, caused by this waste of fall, is estimated as equal to that of 10,000 horses. In the minor channels constructed in modern times, the reasonable slope of from 24 to 30 inches per mile has been adopted.

The most important works on the canal of Caluso are,

1st, The grand dike, or river wall, to defend the head of the canal against the attacks of the Orco, which have occasionally been very fierce and destructive. It is built of cut stone throughout a length of 912 feet, and is connected with the regulator of the canal, the escape, and the distributing edifice of Castellamonte; the whole forming an imposing and well-executed mass of masonry.

2d, The tunnels of San Giorgio, to which brief reference was previously made. The first, called the tunnel of Bioleto, has a length of 2273.60 feet (693 metres); and the second, the tunnel of Fenoglio, of 2374.72 (723.80 metres). Both have a section of 10.15 feet wide at bottom, 12.18 high to the springing of the arches, and 14.72 feet under the crown. The piers and arches are of massive masonry; and the interval which separates the two is occupied by a channel 141 feet in length, of which 121 feet are covered by a bridge-aqueduct, carrying the waters of the canal across the small torrent Madenzone.

3d, The aqueduct under the torrent Malesina, with its attached canal-escape, and the aqueducts of Rivoalto, Luisetto, and Fenoglio.

4th, The most remarkable among the irrigation outlets are those of Nagliè and Nosiglia, belonging to the Commune of Caluso, and the dividers (*partitori*) of Arré, the property of the Conte della Trinità, with those of Verolengo, Rondizzone, and Mandria.

The other works of the canal may be merely enumerated to show their number and extent.

1. Bridges in masonry, the property of the royal domain, .	23
2. Bridges in masonry, serving also as bridge-canals for the passage over the channel of the drainage-water from the adjoining country, ...	9
3. Bridges with superstructures of wood, the property of the royal domain, ...	4
4. Masonry bridges and bridge-canals, the property of private individuals or communities, ...	16
5. Bridges with superstructures of wood, belonging to private parties, ...	7
Total of bridges, . .	59
6. Wooden aqueducts for carrying water for irrigation across the canal, for the use of the royal domain, ...	18
7. The same for the use of private parties, ...	8
Total, .	26

The excessive fall of the bed has rendered it necessary to protect the banks in many places by masonry revetments, of which the united length is shown below.

	Feet.
On the right bank, revetments in masonry, ...	3128.41
On the left bank, ...	1587.91
Total, .	4716.32
On the right bank, revetments in dry-stone masonry,	28585.21
On the left bank, ...	7921.21
Total, .	36506.42

Revetment in planking has also been had recourse to, to prevent the slipping of the sandy soil, and to check infiltration. The total length of planking on both banks is 1171 feet.

The same excessive fall which has necessitated the construction of so much side-revetment for the protection of the banks, has led also to the bed being in many places paved with stone. The total length of the stone pavement is 21516.85 feet.

The number of water-wheels established on the canal for the use of mills, manufactories, and other works, is twenty-two.

The expense of the construction of canals in Piedmont was a point on which I was anxious to procure as many data as possible, for comparison with our results in India, and the following is the official estimate of the total cost of the canal of Caluso. I found the records of the canal department at Turin very deficient in information of this kind. The remote period at which most of the canals were constructed was the principal reason assigned for this deficiency; but it did not appear to me by any means a satisfactory one, as I can see no difficulty in forming at least an approximate calculation for the others similar to that now given for the Caluso works. I have reduced the various amounts given in the new *lira* of Piedmont—which is equal in value to the French franc—to their values in English money, assuming the *lira* to be worth tenpence.

1. Value of the land occupied by the canal-bed and banks,	£1,666	13	0
2. Excavation,	8,125	0	0
3. Temporary dam, head-channel, and banks at head,	1,458	6	0
Carry forward,	£11,249	19	0

	Brought forward,	£11,249	19	0
4.	Regulator, escape, divider of Castellamonte, and guard-house,	1,666	13	0
5.	Tunnels of San Giorgio and connecting aqueduct,	12,500	0	0
6.	Bridges and bridge-canals in masonry,	3,541	13	4
7.	Bridges in wood,	41	13	4
8.	Aqueducts of wood across canal,	50	0	0
9.	Walls and fall of Cassone,	116	13	4
10.	Retaining-walls of masonry,	1,250	0	0
11.	Retaining-walls of stone,	1,666	13	0
12.	Planking,	50	0	0
13.	Paving of the bed,	625	0	0
14.	Dividers of Arré, Mandria, &c.,	1,075	0	0
15.	Sundry expenses of various kinds,	1,075	0	0
	Total,	£34,908	5	0

Whence it appears that the average cost of the canal of Caluso has been rather more than £1700 per mile. It may be interesting to compare this for a moment with the results on the canals of Northern India. The grand Ganges canal has a volume of water very nearly twenty times as large as that of the canal of Caluso; its cost per mile will not exceed one-half the amount shown above. The western Jumna canal has a discharge about eight times as great as that of Caluso; its cost per mile has been about one-eighth of the sum exhibited above. The eastern Jumna canal, the most expensive of all the British Indian lines, has a volume twice as great as that of the canal of Caluso, and its cost has been about one-third the sum given above per mile. Now there is not a larger proportion of masonry-works on the Italian than on the Indian canals, nor are the difficulties of execution greater on the former than on the latter. The expense incurred for land is not a very important item in the cost of the Italian lines. The cause of the difference of expense becomes at once apparent, when the value of labour in the two countries is contrasted. The labourer in Northern Italy receives, on an average, about four or five times the

amount given to the same class of workmen in India; and as this difference is even greater in all artificers' work, while every sort of material is affected by the increase, there is no difficulty in understanding how it is that our canal-works are so much cheaper than those of Piedmont.

The original errors of construction in the Piedmontese canals have entailed heavy expenses; but as the history of our own canals presents errors not less extensive, and not less costly to rectify, I have not removed the items attributable to these causes from the list. The difference of the value of labour affords the true clue to the difference of cost in the execution of the works in the two regions adverted to.

The annual repairs of the works cost generally only the small sum of about £300, and the salaries of establishments about £200—that is, about £25 per mile per annum.

To complete the financial view of the canal of Caluso, I have now to give a few details of the returns derived from it by government and the community. These divide themselves naturally into two classes—1st, The indirect, and, 2d, The direct returns. To the former I have already adverted in a preceding paragraph.

The canal channel is capable of carrying upwards of 470 cubic feet per second, but its maximum discharge, during the greatest heats of summer, does not exceed about 440 cubic feet. By a very careful measurement made by the government engineers, it appears that of this quantity only 349.35 cubic feet per second are utilised for purposes of irrigation, the difference being lost by filtration, evaporation, and other causes.

It is generally calculated in Piedmont that a volume of water, equal to one cubic feet per second, is sufficient for the effective irrigation of very nearly fifty-five acres

of land. Hence the canal of Caluso is capable of irrigating 19,214 acres, but actual measurement reduces this quantity to 17,955, which may be taken to represent the effective area of irrigation. I mentioned before that the excess of rent due to irrigation is estimated at 12s. per acre; hence the indirect returns may be shown thus—

17,955 acres at 12s. per acre, ...	£10,773	0	0
One-sixth of the nét returns from mills, &c., .	200	0	0
Total indirect returns,	£10,973	0	0

The latter item is derived from various minor concessions for the use of the waters of the canal, as a motive power for which the state receives no direct payments. About £11,000 per annum represents, therefore, the indirect returns derived from the canal.

The direct returns, or the annual rents paid by the various consumers of the water, amount to about £1780. Deducting the annual expenses of repairs and establishments, there results a net revenue of nearly £1280, or about four per cent on the capital invested. I may mention here that the Government of India derives from its works of irrigation a per-centage on the capital invested in them ranging from six to nine times the amount here shown, with indirect returns of scarcely inferior proportions.

The price at which water is sold to the cultivators on the canal of Caluso is a point of considerable interest. From 1760 to 1800, the price varied from about £7 to £9 per cubic foot per second; or, assuming this quantity of water to be sufficient for the irrigation of fifty acres of land, from about 2s. 10d. to 3s. 7d. per acre. At the present time the cost of a permanent supply of water is

between £7 and £8 annually per cubic foot per second, or very nearly 3s. per acre. The price, of course, varies somewhat with the demand, but the preceding statements give a fair general idea of the value of water in this part of Piedmont. It is a little less than twice the amount charged in Northern India, where irrigation is given at a cost to the cultivator of about 1s. 8d. per acre, regard being had solely to the price of the water.

It may, perhaps, be useful for reference, if, in concluding this account of the canal of Caluso, I condense into tabular form some of the numerical data given in the preceding pages.

No. I.—Historical and Descriptive Data connected with the Canals from the Dora, Stura, and Orco.

	Supplying river.	Date of construction.	Position of the head-works.	Bridges and aqueducts. Public Property. Masonry.	Bridges and aqueducts. Public Property. Wood.	Bridges and aqueducts. Private Property. Masonry.	Bridges and aqueducts. Private Property. Wood.	Length of canal.
								Miles.
1. Canal of the Veneria, .	Dora,	1750	Pianezza,	21	...	2	...	8
2. Canal of the manufactories in the Royal Park, . .	do.	1775	near Turin,	13	...	...	...	2½
3. Subsidiary do., . .	do.	1655	do.	3	...	...	1	1
4. Canal of Fiano, . .	Stura,	1750	Cafasso,	10	2	...	...	10
5. Canal of the Veneria, .	do.	1740	Robassomero,	7	...	...	...	5
6. Subterranean channel,	do.	1790	Turin,	...	...	...	...	3
7. Canal of Caluso, .	Orco,	1556	Spinetto,	32	22	16	15	20
Totals,	...	...	...	86	24	18	16	49½

No. II.—Agricultural and Financial Data connected with the Canals of the Dora, Stura, and Orco.

	Discharge in cubic feet per second.	Area of land irrigated in acres.	Price of water.		Annual expenditure.	Annual income, net.	Area of irrigation in acres per cubic foot of discharge per second.
			By fixed outlet per cubic foot.	By surface irrigated per acre.			
1. Canal of the Veneria, . .	70	500	..	2s. 6d.	£100	£28	..
2. Canal of the manufactories, .	200	250	..	do.	32	17	..
3. Subsidiary do., . .	90	..	..	..	20	..	..
4. Canal of Fiano, . . .	48	950	8s. 6d.	2s. 6d.	28	46	..
5. do. of the Veneria, . .	12	200	..	do.	12	..	..
6. Subterranean do., . .	0.5	..	..	..	..	..	..
7. Canal of Caluso, . . .	349	17,955	£7 to £8	3s.	500	1,280	51
Totals,	769.5	19,855	..	..	£692	£1,371	..

SECTION IV.

CANALS FROM THE RIVER DORA-BALTEA.

In crossing the Dora-Baltea, we enter upon a tract of country situated between that river and the Sesia, richly supplied with canals of irrigation. The whole of the works within it have, by degrees, become the property of the state, and are administered by engineers acting directly under the ministry of finance. Attached to this department of the ministry is an *Uffizio d'Arte*, or office of works, under the cognisance of which all projects for irrigation are brought. It is entirely separate from the general department of public works, which is intrusted to a different ministry; and the reason assigned for this division is the relation of the irrigation canals to the revenue of the state, which gives to the finance-minister

a deeper personal interest in their efficiency and extension than his colleagues can be supposed to have. The general control and supervision of the department is invested in the Intendant-General of Finance, the chief executive officer under the minister himself. The office of works, according to the latest statement accessible to me—namely, the Parliamentary Estimates for 1851—is organised as follows :—

Engineer-Inspectors, ...	5
Sub-Engineer-Inspectors, ...	2
Engineer cadets, ...	1
Engineer assistants of different grades, ...	6
Total,	14

A staff of fourteen educated engineers carries on the executive duties of the department, but the attention of these officers is restricted entirely to the works. The financial and distributive details are arranged exclusively by the party or parties to whom government has granted the lease of the canals, which are farmed ordinarily for periods of nine years. There is thus an entire separation between the executive and the financial departments—an arrangement which did not appear to me to work successfully. The engineers had not the same keen interest in spreading the benefits of irrigation, as they would have had if their professional characters had been more directly concerned in the extension of the works and the increase of the revenue; while to farm to contractors, or, as at present, to a single contractor, the whole of the waters the property of the state, seems very objectionable. A preferable arrangement would certainly be, to make each superintendent of a canal responsible both for the works and for the collection of the revenue within his own district, and so have the natural benefit of emulation between the different

superintendents, instead of the deadening influence of a general monopoly in the hands of one or two persons. I am quite sure of this, that the irrigation system of Northern India would never have made the progress it has done, if responsibility for the revenue and charge of the works had not been vested in the same individuals. It is impossible for any one to be zealous in the execution of works, for the results of which the credit is to be reaped by other parties; and I am satisfied, from what I observed, that the working of the Piedmontese system is an illustration of this fact.

The emoluments of the canal engineers appear to us very small, but they are in just proportion to those of public officers generally throughout the country. The engineer-inspectors receive about £120 per annum, the sub-inspectors about £80, and the assistants generally from about £70 to £40, according to grade.

The subordinate permanent establishment for the royal canals consists of one chief guardian and thirty-five ordinary guardians. These men have the local charge of the works, and reside in houses supplied for them on the banks of the different canals. They are generally an intelligent class, and particularly expert in all minor arrangements connected with the practical management of the works, and the distribution of the waters. They have considerable power in relation to the agricultural community, as they are intrusted with the keys of the different irrigation outlets in their districts. As their emoluments are very small, it will surprise no one to hear that a power of this kind is not left inoperative—that, in fact, here as elsewhere, power and poverty do not coexist without the natural results of their union being observable; and the legitimate gains of the guardians on the canals in Piedmont, like those of our own guardians in

India, are held to bear but a small proportion to their illegitimate ones. The chief guardian receives a salary of about £24 per annum, and the others from £15 to £20, according to standing in the service.

In the hands of the farmer of the canal revenues are vested the powers of entering into contracts for water with all the cultivators—of fixing, in communication with them, the annual rent to be paid, and the manner in which the supply of water is to be issued and measured. In a word, the whole interior economy, so far as the granting of water is concerned, is under the control of this party, who has his own private agents spread over the country to watch his interests and carry into execution his orders, all disputes being submitted to the decision of the ordinary tribunals.

This outline of the organisation of the canal department being premised, we may now proceed to the description of the canals of the Dora-Baltea.

I. CANAL OF IVREA.

The waters of the Dora-Baltea bear with them from the mountains a very large proportion of sandy matter; and hence, when the canal of Ivrea was first opened in 1468, under the regency of the Duchess Violante, sister of Louis XI. of France, and wife of Amadeo IX., duke of Savoy, its channel became very soon choked up by deposits of this material, and, after an existence of about ninety years, was totally abandoned in 1564.

After remaining nearly a century in this neglected condition, the right to the channel was acquired by the Marquis of Pianezza, who reopened it at his own expense in 1651. Since that period up to the present time, the operation of the canal has been uninterrupted. It was once

used, to a very limited extent only, as a canal of navigation, for which, however, its excessive fall, ranging as it does from 4 to 5½ feet per mile, makes it very inefficient. The proprietary right to the canal remained in the family of Pianezza for 169 years, and during that time continued to afford a considerable revenue. In 1820, the canal, with all its subordinate channels, was acquired by the state, and since that time has been administered by the finance department.

The canal of Ivrea is the highest in position of the various derivatives of the Dora-Baltea, and its head is situated on the left bank of that river, at a point immediately under the town of Ivrea. Its supply is obtained by means of a long and massive dam of wood and stone work, carried from the immediate vicinity of the bridge across the Dora, in a direction oblique to the stream, as far as the regulator at the mouth of the canal—a distance of about 1500 feet. From Ivrea the canal flows in a south-easterly course to a little distance beyond Cigliano, when it makes a sudden turn to the northward, skirting the high banks of the valley of the Dora for a distance of about five or six miles, after which it again changes its direction, and flows eastward to Vercelli, where its surplus waters finally fall into the Sesia. The sectional area of the main line is gradually diminished, according to the distance from the head, in the following proportions :—

	Distance.	Mean Breadth.
From the mouth to La Rocca,	20 miles.	27.7 feet.
From La Rocca to San Germano,	17 ...	23.2 ...
From San Germano to Vercelli,	7.64 ...	17.68 ...
Total length,	44.64	

I have already had occasion to mention that the slope of the bed is very great, being from four to five and a half

feet per mile. One advantage, however, is derived from this excessive fall, in the channel being, to a certain extent, kept clear of silt-deposits by the self-acting velocity of the stream, which carries forward the sand, and ultimately discharges it through the escape-lines, or, when there is water sufficient, into the Sesia. When I saw the canal it would have been difficult to infer, from the appearance of the water, that such large quantities of sand were really deposited from it, for it looked as clear as crystal. But it was only necessary to notice the mounds collected at the outlets of every secondary channel, and to observe the effect of any check to the velocity from local causes, in leading to the immediate formation of sandbanks, to be assured that the characteristic of the waters of the Dora was well founded. It will be some comfort to my brother officers in India to know that an evil from which our canals suffer so much is scarcely less developed in the present case than it is with us.

There is some doubt as to the precise discharge of the canal, it being differently stated by different authorities. I prefer following the estimate of M. Michela, who, as chief of the office of works in the canal department, ought to know best. According to this estimate, the volume of the canal is nearly seven hundred cubic feet per second in the height of the irrigating season, falling to about two hundred and forty cubic feet in the winter time. The area of land irrigated by this supply amounts to thirty thousand acres, thus giving $42\frac{3}{4}$ acres as the extent of land watered by each cubic foot of discharge per second—a little less than the quantity assumed by the engineers in their estimates. This, however, is probably due to the fact that rice cultivation is largely developed on the canal of Ivrea; and as this cultivation requires nearly double the quantity of water

necessary for ordinary meadows, the comparative results obtained in this case are scarcely fair average ones.

The price of water has varied considerably in this district, and, with the progressive improvements of the works, and the consequent increased certainty of supply, it has continued to rise. Anciently, the price was as low as £8 per cubic foot per second, but at present it is nearly three times this amount, or about £21 per annum for the above quantity, which gives an average rate of about eight shillings an acre, or four times the amount paid in India. When the water can be used only for the irrigation of Indian corn, the price is not so high, being between £16 and £17 annually per cubic foot of continued discharge. In the case of rice cultivation, the water is paid for, after a special arrangement, by certain proportions of the produce, ranging from one-sixth to one-eighth, according to local circumstances; and on calculating this amount in money, I find it gives a rate of from about ten to sixteen shillings an acre.

From the main line of the canal there diverge a large number of minor channels, which distribute the waters in detail over the face of the land. Among these the following six are the most important:—

	Discharge in Cubic Feet per Second.	Length.	Mean Breadth.
1. Canal of the Mandria,	96	10¼ miles.	13.01 feet.
2. ... of Tronzano,	70	4½ ...	9.84 ...
... of Cigliano, .	...	14 ...	15. ...
3. ... of Crova, . .	24	3 ...	11.04 ...
4. ... of Termine, .	16	2 ...	7.07 ...
5. ... of Salasco, .	50	4 ...	13.01 ...
6. ... of Robarello, .	16	2¼ ...	8.01 ...
Totals, .	272	40¼	„

In addition to the above, there are a number of other channels for escapes, mills, and for reuniting the supplies

derived from various springs which feed the canal, of which I need only give the names and lengths here, as they present no features of special interest.

	Length in Miles.		Length in Miles.
1. Escape line of Travi, .	½	Brought forward,	11½
2. Mill Channel of Pianezza,	1¾	9. Escape of Maddelena,	...
3. Ditto of the Torra, .	¾	10. Springs of Stella, . .	½
4. Ditto of Pratosecco, .	3	11. Ditto of Luere and Bagliona, . . .	2
5. Escape of Albiano, .	2¼	12. Ditto of Valasse and San Grato, . . .	¼
6. Ditto of Tina, . .	1	13. Ditto Ronco and Ronchetto,	¼
7. Ditto of Borgo Masino,	1½		
8. Ditto of Margherita, .	¾		
Carried forward,	11½	Total miles,	14½

Hence, therefore, the total length of the canal of Ivrea, with its branches, is as below :—

	Miles.
Main line, ...	44.64
Principal branches, ...	40.50
Minor channels, ...	14.50
Total length, .	99.64

It will illustrate the liberal manner in which cross communications are provided for when I mention that, on the main line, from the head to La Rocco, a distance of 20 miles, there are 23 bridges in masonry ; and that besides these there are 8 aqueducts, 4 escapes, with numerous irrigation outlets of various sizes. From La Rocco to San Germano, a distance of 17 miles, there are no less than 23 bridges, with 7 outlets for the branches of the main canal, a siphon, aqueduct, and several mills. From San Germano to Vercelli, a distance of 7 miles, there are 9 bridges and 2 aqueducts. The minor channels are equally well supplied; for on the canal of the Mandria, 10½ miles in length, there are 28 bridges and 6 aqueducts ; on that of Azigliano, 24 bridges and 7 aqueducts ; on that of Crova, 4 bridges—and so on, there being never less than one

bridge at least to every mile of channel, and generally more.

The total income derived by the state from the canal of Ivrea, including rent of mills, &c., amounts to nearly £6000 per annum. This is levied from the following thirty-two districts or communes, which are supplied with water from seventy-three irrigation outlets, of various dimensions. The districts under irrigation are Ivrea, Albiano, Tina, Vestigne, Masino, Borgo-Masino, Moncrivello, Villaregia, Cigliano, Saluggia, Livorno, Bianzé, Borgo-d'Alice, Trenzano, Santhia, San Germano, Tronzano, Crova, Azigliano, Salasco, Cascine-di-Stra, Olcenengo, Veneria-Vercellese, Casalrosso, Viancino, Lignana, Selve, Dezzana, Costanzana, Stroppiana, and Vercelli.

The annual expenditure amounts to £1291, 13s. for repairs of the various works, and about £290 for salaries of the establishment in executive charge of the canal; or, in all, to nearly £1580 per annum. This gives a rate of about £19 per mile of length—including the main line and the principal branches—for the annual expenses of the canal, and leaves to the state a net income of £4420. What the capital invested in the canal is, I was unable to discover; but I was informed that no canals in Piedmont returned more than four per cent on the money sunk in their construction. As the area of irrigation from the canal of Ivrea amounts to 30,000 acres, the indirect returns from increase of rent within the district under its influence may be estimated at about £18,000 per annum.

II. CANAL OF CIGLIANO.

The canal of Cigliano was constructed between the years 1783 and 1790, during the reign of Vittorio

Amadeo III. It is the second derivation from the Dora-Baltea, and has its head-works situated at La Rona, a spot about four miles below the town of Ivrea. Its supply is procured by means precisely similar to those employed in the case of the canal of Ivrea—namely, by a wood and stone work dam carried obliquely across the bed of the river, and having connected with it a regulating bridge with sluices and escape. After flowing for about 20 miles, its surplus waters fall into the river Elvo, in the district of Carisio. The breadth of its channel decreases gradually from about 26½ feet at the head to about 15 feet at the tail.

The only branch derived from the canal of Cigliano is that of Saluggia, executed also about the close of the preceding century. It has a length of about 10 miles, a mean breadth of about 16 feet, and a depth of 4 feet, carrying a volume of water equal to 60 cubic feet per second.

On the canal of Cigliano there are 25 bridges and 5 aqueducts or siphons; and on the branch of Saluggia there are 25 bridges and 8 aqueducts—in all 50 bridges and 13 aqueducts. There are also 7 mills and 1 foundry, the property of private individuals.

The discharge of the canal is nearly the same as that of Ivrea—viz., about 650 cubic feet per second. The area of irrigation from the main canal and the Saluggia branch is estimated at 32,500 acres, thus giving exactly 50 acres as the area of irrigation due to each cubic foot of continued discharge. The lands irrigated are comprised within the following seven districts: viz., Villareggia, Cigliano, Livorno, Bianzé, Tronzano, Santhia, and Carisio.

The annual income of this canal is estimated at £5625, and its expenses for repairs and establishment at £420,

or about £14 per mile. The net income received by the state is therefore £5205 per annum. The indirect benefits derived from the canal may be estimated at from £19,000 to £20,000 a-year.

The price of water on the canal of Cigliano is precisely the same as on that of Ivrea—viz., about £21 per annum for each cubic foot per second, or about 8s. an acre, and for rice land from 10s. to 16s.

III. CANAL DEL ROTTO.

This canal is the third and lowest of the lines derived from the Dora-Baltea. It was, however, the earliest constructed, having been opened in 1400 by order of Duke John of Montferrat, by whom the head-works were originally established in the district of Saluggia. But inconvenience having been experienced in this position, the dam was ultimately established in the district of Mazzé, at a place called Rivarossa, a little above the bridge on the Rondissone road.

The arrangements at the head are similar to those of the two preceding canals. The length of the main line is about 8 miles, the breadth of the channel at the head 24.18 feet, and the depth 5.84 feet. Two main branches are derived from the Canal del Rotto: 1st, The branch della Camera, constructed at the same time as the main canal, which has a length of 22½ miles, a mean breadth of 18 feet, and a discharge of about 120 cubic feet per second; and 2d, the branch of Riva, constructed in 1838, having a length of 18 miles, a mean breadth of 14 feet, and a discharge of about 60 cubic feet per second.

The discharge of the main canal is about 600 cubic feet per second, of which 150 are appropriated to increasing the supply of the canal of Saluggia, a derivative of

the canal of Cigliano, which intersects the present line, and in truth derives from it a larger proportion of its volume than is given by the parent stream. The 450 cubic feet which remain are utilised in the main canal and its two branches. The total area irrigated thereby is about 25,000 acres, being about 55 acres to each cubic foot per second.

The total annual income derived from the Canal del Rotto is £5000, and its annual expenses amount to £625. The net income is therefore £4375, and the indirect returns may be estimated at about £15,000 per annum.

When I visited the line, I found a small branch in progress of execution for the irrigation of the high-lands of Tricerro, and as it was as nearly as possible of the same dimensions as the distributing channels of our Indian canals, I was interested in learning its cost. Its length was nearly 2¾ miles—it was carried over a somewhat difficult country, having a highly embanked channel and some heavy masonry works. Its cost had been 68,000 francs, or very nearly £1000 per mile. Works of the same kind are executed with us at as nearly as possible one-tenth of the above sum, or £100 per mile.

The districts irrigated by the canal under notice are, Saluggia, Crescentino, Fontanetto, Pallazuolo, Trino, Grangia di Pobietto, Torrione, Morano, Balzola, Villanova, Livorno, and Lucedio. For cross-communication between these districts, the main line is provided with 14 bridges, the branch of the Camera with 31, and that of Riva with 25 bridges. There are also 3 aqueducts on the main line, and 5 on that of the Camera—in all 70 bridges and 8 aqueducts, with 7 sets of mills, and 1 foundry.

The lines of canal indicated in the preceding and present sections of this chapter are those to which the tract

of country included between the Orco and the Sesia is chiefly indebted for its agricultural prosperity. The latter river furnishes but a single derivative on its right bank, the canal of Gattinara, and its influence is not great. But in addition to the main lines we have already adverted to, there is an immense number of minor channels, which at various times have been executed at the cost of the communes through which their supplying streams pass; and though each of these individually may be of small dimensions and volume, still the aggregate area of irrigation formed by them is of serious importance.

From the Malesina and minor tributaries of the Orco, and directly from that river itself, many of these little streams have been drawn, as, for example, the canals of the communes of San Pons, of Valperga, of Salasso, of Fabria, of Rivarolo, &c., on the right, and those of Salto, Courgné, Castellamonte, Aglié, Ozegna, San Giorgio, San Guisto, Foglizzo, Montanara, and Chivasso, on the left banks of the latter river.

From the Chiusella, a tributary of the Dora-Baltea, the canal of Parella, and the communal canals of Gavone, Perosa, &c., are derived. From the Elvo, a tributary of the Sesia, there are two canals of considerable importance —one the canal of Cavallera, originating to the northward, and the other of Molinara, to the southward of Carisio. The latter has a discharge of from 80 to 100 cubic feet per second, of which a considerable proportion is derived from rich springs in the vicinity. In addition to these, however, the Elvo supplies numerous smaller channels, as those of Fausano, Canapali, San Pietro, Casanova, &c., on the left bank, and on the right the canals of Piano, Marchesa, Vestigne, Porta, Quinto, and Vercelli. Similarly, the Cervo, another tributary of the Sesia, and the

upper Sesia itself, supply a considerable number of these communal channels. The entire area thus irrigated between the Orco and the Sesia, though not capable of very rigid determination, may safely be estimated at not less than 28,000 acres.

I will now give for the canals of the Dora-Baltea tabular statements similar to those with which the last section concluded.

No. III.—Historical and Descriptive Data connected with the Canals of the Dora-Baltea.

	Supplying river.	Date of Construction.	Position of head-works.	Bridges and aqueducts. Public. Masonry.	Bridges and aqueducts. Public. Wood.	Bridges and aqueducts. Private. Masonry.	Bridges and aqueducts. Private. Wood.	Length of channel in miles.
1. Canal of Ivrea—	Dora-Baltea.							
Main line, . . .	...	1468	Ivrea,	68	...	...	...	44
Branches, . . .	...	Various,	Various,	212	6	5	15	55
2. Canal of Cigliano—								
Main line, . . .	...	1725 to	Villareggia,	36	25	1	1	20
Branches, . . .	...	1790		10	...	...	...	10
3. Canal del Rotto—								
Main line, . . .	...	1450	Mazzé,	17	...	..	...	8
Branches, . . .	...	Various	...	57	2	22	15	40½
Totals,	...	...	...	400	33	28	31	177½

No. IV.

No. IV.—AGRICULTURAL and FINANCIAL DATA connected with the CANALS of the DORA-BALTEA.

	Discharge in cubic feet per second.	Area of land irrigated in acres.	Price of water. By fixed opening per cubic foot per second.	Price of water. By surface irrigated per acre.	Annual expenditure in pounds sterling.	Annual income net in pounds sterling.	Area of irrigation in acres per cubic foot per second.	Indirect returns in pounds sterling per annum.
1. Canal of Ivrea, .	700	30,000	£16 to £21	8/ to 16/	1580	4420	42¾	18,000
2. .. of Cigliano,	650	32,500	Do.	Do.	420	5205	50	20,000
3. .. of Del Rotto,	600	25,000	Do.	Do.	625	4375	55	15,000
Subordinate irrigation between the Orco and the Sesia,	650	28,000	..	..	..	..	..	16,800
Totals and averages,	2600	115,500	£18, 10s.	12/	2625	14,000	49½	69,800

SECTION V.

CANALS FROM THE RIVERS SESIA, AGOGNA, AND TERDOPPIO.

On reaching the banks of the Sesia, we find ourselves among a class of canals distinguished from those already described, as being exclusively private property belonging either to certain noble families, or associations of families or communities, and occasionally to charitable or religious institutions. The canals derived from this river are too numerous for its available volume of water, and the consequence is, that almost incessant litigation is in progress between their different proprietors as to the quantities each is entitled to have. From all I saw of these private canals, I do not think they are either so well maintained

as regards their works, or so well administered as regards the distribution of their waters, as those in the Vercellese or elsewhere, which are under the direct control of the state.

On the right bank of the Sesia, and therefore contributing to the irrigation of the province of Vercelli, there is but one canal—that, namely, of Gattinara. It is the most ancient canal in Piedmont, having been constructed at the beginning of the fourteenth century by the Marquis of Gattinara, then the feudal proprietor of that part of the country. The head is situated on the lands of the commune of Gattinara, and the supply is derived from the Sesia by means of a temporary dam erected only during the season of irrigation. This supply is far less than the canal is competent to carry, as it amounts only to about 100 cubic feet per second, while the capacity of the channel is sufficient for fully 250 cubic feet.

At about 8 miles from the head, the canal divides itself into two branches, one retaining the original name, the other being called the Cavo, or Channel of Baragia. The whole length of the main line, from the head to the termination in the bed of the torrent Elvo, in the commune of Oldenico, is about 15 miles, with a mean breadth of section amounting to nearly 12 feet. The secondary channel has a length of about $7\frac{3}{4}$ miles, with a mean breadth of $6\frac{1}{2}$ feet. The total length, therefore, is $22\frac{3}{4}$ miles, the whole of which is the property of the family of the Marquis of Gattinara. The supply of water is exceedingly inadequate to the demands of the district, and the extent of irrigation from the canal is estimated at only about 4500 acres, being 45 acres for each cubic foot of discharge per second.

In former times, when the quantity of water was in better proportion to the capacity of the canal, the revenue

was considerable, amounting to from £3000 to £3500 per annum, the water selling at from £8 to £10 per cubic foot; but now when the supply is so imperfect, the returns have fallen off very much, and do not probably exceed a fourth part of the sums above noted.

The communes to which the canal of Gattinara and its branches supply irrigation are those of Gattinara, Lenta, Gistarengo, Arborio, Greggio, Albano, Oldenico, Roasendo, Cascine di San Giacomo, Buzenzo, and Bollono.

Crossing the Sesia, and entering the province of Novara, we find a succession of canals derived from the left bank of the river, which will be most conveniently described in their order of succession.

I. CANAL, OR ROGGIA MORA.

The highest of the canals derived from the Sesia is the canal Mora, so called because the old channel, which had originally been opened by the city of Novara at an unascertained date, was enlarged and extended in 1481 by Ludovico Sforza il Moro, Duke of Milan, under whose dominion the country up to the Sesia was then placed. This prince caused the old canal to be prolonged until a junction was effected with the canal Sforzesca, another of his works in the immediate vicinity of the town of Vigevano. The total length of the canal is 32½ miles, and its breadth varies from 26 to 20 feet. It is capable of carrying a volume of not less than from 450 to 500 cubic feet per second, but the actual quantity which it receives from the Sesia does not exceed 130 cubic feet. With this discharge it irrigates about 7000 acres in the communes of Ghemme, Sizzano, Fara, Vignale, Novara, Trecate, Cerano, Cassolo, and Vigevano. Its head is

situated at Romagnano, in the province of Novara, where a dam of the ordinary construction is carried across the bed of the river.

A considerable proportion of the supply of the canal Mora produces no revenue whatever, in consequence of grants of water in perpetuity, and free from all charges, having been made to various individuals from very ancient dates. These parties enjoy their privilege at no farther charge than for a certain proportion of the expenses incurred for the maintenance of the canal. The proprietorship of the canal is vested in the families of Saporiti and Beauregard, and at present it affords them a revenue of from £800 to £1000 per annum. The price of water in this part of the country is high, being about £31, 10s. per cubic foot per second—or on an average from 14s. to 16s. per acre. I found it impracticable to obtain any very minute data connected with the expenses and returns of this or other private canals, as their records were not accessible; but as they are not works of great importance, perhaps the points ascertained are all that are of any special interest. I have already mentioned in Part I. that the works of the canal Mora appeared to me to be in very indifferent order, and I saw nothing connected with them deserving of particular record.

From the same head as supplies the canal Mora, a second canal of Gattinara is derived for the irrigation of the lands of the commune of the same name. It is only about 2¼ miles in length, and irrigates about 1250 acres of meadow land on the right bank of the Sesia, with a volume of water equal to 22½ cubic feet per second. The proprietorship of the canal is vested in the commune, and the inhabitants have a right of gratuitous irrigation, dividing among themselves also about £250 per annum, as the rents of several mills situated on the canal.

II. CANAL, OR ROGGIA BUSCA.

The head of the canal Busca is situated in the commune of Ghemme, province of Novara, about six miles below that of the Canal Mora. The works date from the close of the fourteenth century, having been constructed by the family of Crotta-Tettoni between 1380 and 1382. The channel was, however, abandoned for nearly two centuries and a half, and was reopened after this long interval at the expense of the family of Busca-Arcenati-Visconti, whose name it now bears. Like all the canals of the Sesia, its actual volume is very small as compared with the capacity of its channel; the latter being adapted to a discharge of about 350 cubic feet per second, while the former does not exceed 65 cubic feet. Its area of irrigation amounts to 6915 acres, which would give the unusual quantity of 106 acres for each cubic foot of discharge, just twice the average area in the Vercellese. As my authority for this statement is M. Michela, perhaps the best in Piedmont, I am not disposed to regard the result with doubt. It shows in a striking manner how much more work, so to speak, can be done by the same quantity of water, when the circumstances of the locality compel the most rigid economy and care in the distribution and use of the waters. The supply is so valuable that scarce a drop is wasted, and the most minute precautions are taken to insure the maximum of irrigation from it. A necessary consequence of this state of affairs is, that the cost of water is high. The annual charge for one cubic foot per second is about £28. The revenue derived from the canal, however, is very trifling, as the water has been almost entirely alienated by gratuitous grants in perpetuity to different parties.

The total length of the canal is nearly 18 miles, and it is carried through the lands of the following thirteen communes, viz., Ghemme, Carpignano, Silavenzo, Mondello, Biandrate, Casaleggio, Orfengo, Confienza, Robbio, Castel-Novetto, Rosasco, Cozzo, and Valle. Twelve subordinate channels distribute the waters over the face of the country, whose denominations and length are given below.

	Length in Miles.		Length in Miles.
1. Canal San Pietro, . .	4	7. Canal Passini, . .	½
2. „ Casale, . . .	3	8. „ Ranzini, . .	½
3. „ Ghileri, . . .	2	9. „ Ferraris, . .	¾
4. „ Ajassa, . . .	1	10. „ Panizzari, . .	¾
5. „ Valle, . . .	¾	11. „ Caccia, . .	1¾
6. „ Roggiola, . .	5	12. „ Livello, . .	1¼
	15¾		5½

The total length of the canal and its minor channels is therefore about 39¼ miles. The main line has a breadth at the head of about 20 feet, and the distribution channels range from 4 to 10 feet wide, according to their volume of water.

III. CANAL RIZZO-BIRAGA.

This canal is the third in order on the left bank of the Sesia: a common dam across the river secures the supply, which at present does not exceed 90 cubic feet per second. The line was opened in 1488 by the Marquis Rizzo di Biraga, under authority of a grant from Ludovico Sforza, Duke of Milan. The head is established in the district of Casignano, province of Novara, and the channel is carried through the districts of Biandrate, Confienza, Cameriano, Vespolate, Marza, terminating in that of Zemme by junction with the river Agogna, after a course of about 17 miles. The volume of water being 90 cubic feet per second, the area of irrigation is 9052.78 acres, or 100.6

acres for each cubic foot per second—nearly the same as on the canal Busca. The price of the water is also the same as on the last-mentioned canal, or about £28 per annum for each cubic foot of continued discharge per second. Gratuitous alienations absorb the whole of the supply of this canal, so that only a very trifling direct revenue is derived from it. Twenty-two minor channels diverge from the main line, of which the names and lengths are given below :—

		Length in Miles.			Length in Miles.
1.	Canal Molinara, . .	$1\frac{3}{4}$		Brought forward,	37
2.	„ Cascina dei Prati,	$2\frac{1}{2}$	13.	Canal Panizzari, .	2
3.	„ Rondona, . .	$2\frac{1}{2}$	14.	„ Communale, .	1
4.	„ Oriate, . .	$6\frac{1}{4}$	15.	„ Gallarati-Scotti,	$2\frac{1}{4}$
5.	„ Sabajno, . .	5	16.	„ Cantalupa, .	$1\frac{1}{2}$
6.	„ Vandoni, . .	$4\frac{3}{4}$	17.	„ Luzzi, . .	$1\frac{1}{2}$
7.	„ Visconti, . .	3	18.	„ Ceriela, . .	$\frac{1}{2}$
8.	„ Pianca, . .	2	19.	„ Mensa, . .	$\frac{3}{4}$
9.	„ Fornasara, . .	$3\frac{1}{2}$	20.	„ Pergolesca, .	$2\frac{1}{2}$
10.	„ Scotti, . .	$1\frac{1}{4}$	21.	„ Cascina, . .	1
11.	„ Chiaramella, .	$2\frac{3}{4}$	22.	„ Biraghetta, .	$21\frac{3}{4}$
12.	„ Gallarati, . .	$1\frac{3}{4}$			
		37			$71\frac{3}{4}$

The total length of the canal Rizzo-Biraga, with its subordinate lines, is therefore $88\frac{1}{4}$ miles.

IV. CANAL, OR ROGGIA SARTIRANA.

This is the lowest in position and the best supplied of the canals of the Sesia. It was opened in 1380 by the Count of Sartirana, and its head was established in the district of Pallesta, province of Mortara, at a point not more than 10 miles above the junction of the Sesia with the Po. It has a total length of nearly 18 miles, and a discharge in the irrigating season of 220.38 cubic feet per second, with which supply it irrigates about 13,860 acres, or 63 acres for each cubic foot. The price of the water

is the highest in the kingdom, amounting to £42 per annum for each cubic foot per second, or to a rate of very nearly 20s. an acre. Although many gratuitous concessions have been made from this canal, it is still a very valuable property, and yields to the family possessing it an annual income of about £3500, in addition to the free irrigation of all their lands.

Nineteen minor channels have been constructed for the distribution of the water to distant points, of which I give as before the names and lengths, with the districts for the benefit of which each line is designed :—

	Length. Miles.	District Irrigated.
1. Canal Langosco, . . .	1	Langosco.
2. " Marchetti, . . .	¾	Do.
3. " Bagnolo, . . .	¾	Do.
4. " Borri, ...	½	Rosasco.
5. " Roggia Nuova, . .	10½	Candia.
6. " Roggiuolo Communale,	1	Do.
7. " San Rocco, . . .	2½	Sartirana.
8. " La Rinalda, . . .	2¼	Breme.
9. " Sentieri, . . .	1	Sartirana.
10. " La Lupa, . . .	¾	Do.
11. " Torre, . . .	2¾	Torreberretti.
12. " Castellaro dei Giorgi, .	4¼	Castell. dei Giorgi.
13. " Ragnera, . . .	1¾	Mede.
14. " Villabiscossi, . .	4	Villabiscossi.
15. " Montriolo, . . .	2	Sartirana.
16. " San Giorgio, . .	2½	Do.
17. " Mede, ...	1	Mede.
18. " Farina, . . .	1½	Semiana.
19. " Borella, . . .	1¾	Goido.
	42½	

The canal Sartirana has therefore an entire length of 60½ miles, and with it we terminate the series of the canals of the Sesia, which have an aggregate length of 225¼ miles, and a discharge amounting to 627½ cubic feet per second, by which about 41,333.78 acres of land are irrigated annually for rice crops, water-meadows, and other products.

It remains now to give under this section a few details of the irrigation from the minor streams by which the tract of country between the Sesia and the Ticino is traversed. As the canals from these streams are small and numerous, I do not think it will be necessary to do more than to give, in a tabular form, some statistical information connected with them. The works present no features of novelty or special interest.

LIST of CANALS derived from the Torrent AGOGNA.

	Length in Miles.	Discharge in cubic feet per second.	Districts Irrigated.	Area of irrigation in acres.	Price of water per cubic foot per second.
1. Canal Crotta, . . .	12¼	19.05	Confienza, Robbio, and Castelnovetto, . . .	1347.5	£35
2. ,, Caccìesca Sorbelloni,	3	14.90	Confienza and Robbio, .	1795	Do.
3. ,, Caccìesca Isambardi,	11¾	14.90	Confienza, Robbio, Ricorvo, and Castel Agogna, .	1800	Do.
4. ,, Colli, . . .	1½	11.38	Ricorvo, ...	1125	Do.
5. ,, Regola, . . .	3¼	19.05	Mortara, Cernago, and San Giorgio, . . .	2695	Do.
6. ,, Olevano, . . .	5	14.90	Olevano, ...	1205	Do.
7. ,, Campalestro, . .	4	22.42	Campalestro and Lumello,	1982.5	Do.
8. ,, Galliavola, . . .	9¼	22.42	Lumello and Galliavola, .	1788.7	Do.
9. ,, Boragno, . . .	5	14.90	Lumello, . . .	577.5	Do.
10. ,, Caffarella, . . .	4	22.42	Galliavola and Mezzanabiglia, ...	1686	Do.
11. ,, Contone, . . .	3¾	11.62	Do. Do.	1270	Do.
12. ,, Traversi, . . .	6¼	22.42	Sannazaro, . . .	2310	Do.
13. ,, Casoni Boroni, . .	3½	11.62	Mezzanabiglia, . . .	550	Do.
	73	222.00		20,132.2	

The average area which is irrigated by each cubic foot per second employed in the canals of the Agogna is 90.6 acres, which indicates very careful and economical use of the water. The price per cubit foot is high, and is the same for all the canals, viz. £35; but owing to the minute distribution of the water, the rate per acre amounts only to 7s. 9d., which, as compared with the canals in the Vercellese, is moderate. The canals of the Agogna, like those of the Sesia, are all private or communal property; and their maintenance is provided for by a rateable

charge on their proprietors proportioned to the advantages each derives from them.

The small river Arbogna supplies four canals, of which the details are given below :—

List of Canals from the River Arbogna.

	Length in miles.	Discharge in cubic feet per second.	Districts irrigated.	Area of irrigation in acres.	Price of water per cubic foot per second.
1. Canal Plezza,	3	3.74	Cernago,	35.0	£35
2. ... Arbognetta,	3	3.10	Ottabiano,	192.5	do.
3. ... San Martino,	4½	4.96	Vallegro,	198.75	do.
4. ... Volpi,	2¾	6.22	Ferrara,	480.0	do.
Totals,	13¼	18.02		906.25	

The average area of irrigation with the waters of the Arbogna is 50.3 acres per cubic foot per second, and the cost per acre is 14s., or very nearly double that on the canals of the Agogna.

The last of the minor streams which contribute to the irrigation of the country under notice is the Terdoppio, from which the following ten canals are derived :—

List

LIST of CANALS from the River TERDOPPIO.

	Length in Miles.	Discharge in cubic feet per second.	Districts irrigated.	Area of irrigation in acres.	Price of water per cubic foot per second.
1. Canal Refredo,	4	8.72	Villanova,	496.0	£35
2. ... San Marco,	5¼	14.90	San Marco,	625.0	...
3. ... Corbetta,	1½	14.90	Gambolo,	577.5	...
4. ... Valsaggia,	1¼	6.22	Tromello and Roventino,	375.0	...
5. ... Molinara,	2	14.90	Tromello,	1155.0	...
6. ... Reale,	2	18.68	Garlasco,	1012.5	...
7. ... Boschetta,	5¼	4.96	Dorno,	385.0	...
8. ... Battera,	5¼	24.90	Dorno,	1125.0	...
9. ... Molino di Sojnera,	3½	12.44	Zinasco,	770.0	...
10. ... Bonbardone,	5	14.90	Bonbardone,	967.5	...
Totals,	35	135.52		7884.5	

The average area of irrigation for each cubic foot per second, in the present instance, is 55.4 acres; and, as the price of water is the same as before, we obtain a rate of nearly 12s. 9d. per acre, which is about the same as in the Vercellese. There is, however, great variety in the area irrigated by the same quantity of water on the different canals; and the rates here given are only designed to give some general idea of the cost of irrigation in each locality.

It appears from the details now given, that the minor streams specified supply in the aggregate 126¼ miles of canal, irrigating 28,506.95 acres, with a quantity of water equal to 375.54 cubic feet per second, thus giving an average area of irrigation for each cubic foot of nearly 70 acres, at a cost of nearly 9s. per acre.

I have now only to condense, into the same tabular forms as have been given for the other rivers, some of the particulars scattered through this account of the canals of the Sesia :—

No. V.—Historical and Descriptive Data connected with the Canals of the Sesia, &c.

	Supplying river.	Date of construction.	Position of head-works.	Bridges and aqueducts. Public. Masonry.	Bridges and aqueducts. Public. Wood.	Bridges and aqueducts. Private. Masonry.	Bridges and aqueducts. Private. Wood.	Length of channel in miles.
Right Bank.								
1. Canal Gattinara, (1.) . .	Sesia	1320	Gattinara	—	—	—	—	23¾
2. Do. do. (2.) . .	Do.	1482	Romagnano	—	—	—	—	2¼
Left Bank.								
3. Canal Mora, . . .	Do.	1481	Romagnano	—	—	—	—	32¼
4. Do. Busca, . . .	Do.	1380	Ghemme	—	—	—	—	39¼
5. Do. Rizzo-Biraga, . .	Do.	1488	Cassignano	—	—	—	—	88¼
6. Do. Sartirana, . .	Do.	1380	Pallesta	—	—	—	—	60¼
7. Canals of the Agogna, .	Agogna.	Various	Various	—	—	—	—	78
8. Do. of the Arbogna, .	Arbogna	Do.	Do.	—	—	—	—	13¾
9. Do of the Terdoppio, .	Terdoppio	Do.	Do.	—	—	—	—	35
Totals,								373

No. VI.—Agricultural and Financial Data connected with the Canals of the Sesia, &c.

	Discharge in cubic feet per second.	Area of land irrigated in acres.	Price of water. By fixed opening per cubic foot per second.	Price of water. By surface irrigated per acre.	Annual expenditure in pounds sterling.	Annual income net in pounds sterling.	Area of irrigation in acres per cubic foot per second.	Indirect returns in pounds sterling per annum.
1. Canal Gattinara, (1.) .	100	4500	£8 to £10	4s.	—	1200	45	2,700
2. Do. do. (2.) .	22.5	1250	Do.	—	—	250	56	750
3. Do. Mora, . .	130	7000	£31/10	14/ to 16/	—	1000	53	4,200
4. Do. Busca, . .	65	6915	28	10/ to 11/	—	?	106	4,029
5. Do. Rizzo-Biraga, .	90	9058·78	28	Do.	—	?	100	5,435
6. Do. Sartirana, .	220·38	13·860	42	20/	—	3500	63	8,316
7. Canals of the Agogna, .	222	20·112	35	7/9	—	?	90	12,067
8. Do. of the Arbogna,	18·02	906	Do.	14/	—	?	50	544
9. Do. of the Terdoppio,	135.52	7488·5	Do.	12/9	—	?	55·4	4,693
Totals and averages,	1003·42	71,090·28					68·6	42,734

SECTION VI.

CANALS ON THE RIGHT BANK OF THE TICINO, WITH SOME DETAILS OF IRRIGATION FROM SPRINGS IN THE COUNTRY BETWEEN THAT RIVER AND THE SESIA.

To complete this sketch of the irrigation of the rich country between the Sesia and the Ticino, I have now to describe briefly the canals derived from the right bank of the latter river. The physical peculiarities of this important stream will be more appropriately detailed when the hydrographic system of Lombardy is described; but I may mention here that the canals derived from it on the Piedmontese bank share in the benefits which the existence of the Lago Maggiore insures. Their supplies are at once more abundant and more regular than those of the canals derived from the other rivers of Piedmont, which flow directly from the mountains without the intervention of any regulating and purifying basins. Hence the value of the waters from the canals of the Ticino is very high, and their influence in stimulating the agriculture of the districts through which they flow has been of the most marked and satisfactory character.

Commencing in the order of succession hitherto observed, we have—

I. THE CANAL LANGOSCO.

This canal was originally constructed about the middle of the fourteenth century, by the family Langosco. It was, however, carried by them only to the bridge of Croscia, in the district of Cerano, as is recorded by an inscription on this work. At a later date it was pro-

longed by the joint exertions, and at the common expense, of the hospital of Pavia, the family Pasquale, and the Cardinal Calderara. At the present time it is the property of the hospital of Pavia, and of several members of the families Busca, Borromeo, Strada, and Litta, who form an association under the name of "The Company of the Canal Langosco."

The head of the canal is situated near Galliate, in the province of Novara, where a dam has been carried across the river for obtaining the supply of water. The total length is about 27 miles, whereof 7½ are in the province of Novara, and 19½ in that of Mortara. The discharge of the canal is equal to 249.06 cubic feet per second, and the area of irrigation extends over 19,142.5 acres, thus giving nearly 77 acres for each cubic foot. The price of the water per cubic foot per second is £42 per annum, or 11s. per acre. On a canal so ancient, many gratuitous concessions of water have been made; and as the association to which it belongs is strictly private, I do not know the precise sum it returns annually.

Thirteen minor channels have been constructed for the distribution of the waters, some few details of which I give below:—

	Length. Miles.	District irrigated.
1. Canal Bellerio, . . .	3¾	Cassolo and Vigevano.
2. „ Calderara, . . .	1¼	Vigevano.
3. „ Roventino, . . .	3	Gambolo and Trumello.
4. „ Gerro, . . .	2	Trumello.
5. „ Conca, . . .	¾	Do.
6. „ Montagione, . .	½	Do.
7. „ Lucini, . . .	5¼	Ottabiano.
8. „ Vallegini, . . .	1	Valleggio.
9. „ Archimbolda and Silvatica, . . .	11½	Valleggio and Scaldassole.
10. „ Del Duca del Vitto, .	3½	Scaldassole.
11. „ Borgo San Siro, . .	2½	Borgo San Siro.
12. „ Regina, . . .	9¼	Ferrara and San Nozzaro.
13. „ Pollini, . . .	3¾	Alagna.
	48	

The total length of the canal Langosco and its branches is therefore 75 miles, and in addition to the eleven districts included in the above table, it irrigates nine more—viz., Galliate, Trecate, Cerano, San Marco, Garbagno, Garbagna, Cascinale, Garlarco, and San Giorgio, throughout nearly the whole of which the land was in a state of wretched sterility, before the canals of the Ticino were brought into active operation.

II. CANAL SFORZESCA.

This is the second important line derived from the Ticino on the right bank. It was constructed originally in 1482, by Ludovico Sforza, duke of Milan, for the irrigation of his extensive and beautiful domain of Sforzesca, near the town of Vigevano. At present the canal belongs to the Count Rona Saporite, the proprietor of the estate Sforzesca. Its head and regulators are established at Galliate, in the immediate vicinity of the head of the canal Langosco. The main line is about $8\frac{3}{4}$ miles in length, and the two small branches, the Naviglietto Sforzesco, and the canal Merengone, are respectively $3\frac{1}{2}$ and $24\frac{3}{4}$ miles long, so that the entire length of the canal is about 37 miles. Its discharge is 215.95 cubic feet per second, and the area irrigated by it is about 14,878 acres, giving 69 acres for each cubic foot. The price of water is considerably lower than on the canal Langosco, being £31, 18s. annually for each cubic foot per second, or about 9s. per acre. In addition to the irrigation just mentioned, the canal supplies the motive force necessary for two corn-mills having eight wheels, five silk-mills, and one cotton factory. As a very large portion of the supply has been alienated for ever by gratuitous grants, the proprietor derives only about £1500 a-year from it, after all expenses of maintenance have been paid.

III. CANAL MOLINARA.—IV. CANAL CASTELLANA.—AND, V. CANAL MAGNA.

These are three small derivations from the Ticino, which irrigate portions of the districts of Cassolo, Garlasco, Gropello, Zerbolo, Carbonara, Santa Maria della Strada, and San Siro. The canal Molinara is 3½ miles in length, with a discharge equal to 25.39 cubic feet per second. With this supply it irrigates 2483 acres, being 99.3 acres for each cubic foot. The price of the water is very moderate, being £22, 15s. per annum for each cubic foot per second, or about 4s. 6d. per acre.

The main line of the canal Castellana is 31 miles in length, and its two branches, the canals Cajroli and Castellanetta are respectively 8¼ and 2 miles long, making the total length 41¼ miles. It has a volume equal to 114.32 cubic feet per second, and irrigates 9125 acres, or 80.4 acres for each cubic foot. The price of the water is £19, 15s. per cubic foot, or about 4s. 9d. per acre.

The canal Magna is only 4¼ miles long, with a discharge of 24.90 cubic feet per second, and an area of irrigation equal to 2040 acres, or 81.6 acres for each cubic foot. The price of the water and the rate per acre are both, as nearly as possible, the same as on the canal Castellana.

I have now completed, as precisely as the materials I have been able to collect will admit, the description of the canals to which the provinces of Novara and Mortara owe their present state of agricultural prosperity. As subordinate to the canal system, but still of no mean importance, I have to advert for a moment to the extent of irrigation within the same provinces from springs, or, as they are locally termed, *Cavi Sorgivi.* The small

canals, fed by springs, amount to no less than ninety-four in number. They have a total length of 467½ miles. They afford for irrigation a supply of water estimated at 788 cubic feet per second, and they actually irrigate 52,500 acres of land. They form, therefore, a very important element in the agricultural system of the district, adding as they do to its rental at least £30,000 per annum. The spring-fed canals are invariably private property: their owners may dispose of the water as best suits their own interests. Various legal enactments, to which I will refer in detail in their proper place, protect the springs from injury, and on their use depends chiefly that great extent of marcite or winter-meadow which is found throughout the two provinces under notice.

I close this section with the usual tables of reference for the canals of the Ticino.

No. VII.—Historical and Descriptive Data connected with the Canals of the Ticino, &c.

	Supplying river.	Date of construction.	Position of head-works.	Length of channel in miles.
1. Canal Langosco, .	Ticino	1350	Galliate	73¾
2. " Sforzesca, .	Do.	1482	Do.	37
3. " Molinara, .	Do.	...	Cassolo	3½
4. " Castellana, .	Do.	...	Garlasco	41¼
5. " Magna, . .	Do.	...	Do.	4¼
6. Spring-fed canals, .	Springs	...	...	467½
	...	...	...	627¼

No. VIII.—AGRICULTURAL and FINANCIAL DATA connected with the CANALS of the TICINO, &c.

	Discharge in cubic feet per second.	Area of irrigation in acres.	Price of Water. By fixed opening per cubic foot per second.	Price of Water. By surface irrigated per acre.	Annual expenditure in pounds sterling.	Annual income net in pounds sterling.	Area of irrigation in acres per cubic foot per second.	Annual indirect returns in pounds sterling.
			£ s.					£
1. Canal Langosco, .	249.06	19,142	42 0	11/	—	—	77	11,485
2. ,, Sforzesca, .	215.95	14,878	31 18	9/	—	1500	69	8,927
3. ,, Molinara, .	25.39	2,483	22 15	4/6	—	—	99.3	1,490
4. ,, Castellana, .	114.32	9,125	19 15	4/9	—	—	80.4	5,475
5. ,, Magna, . .	24.90	2,040	Do.	Do.	—	—	81.6	1,224
6. Canals from springs,	788.	52,500	—	—	—	—	66.6	31,500
	1417.62	100,168	—	—	—	—	—	60,101

SECTION VII.

CANALS FROM THE RIVERS ON THE RIGHT BANK OF THE PO, WITH SOME DETAILS OF IRRIGATION IN THE MOUNTAIN VALLEYS OF PIEDMONT GENERALLY.

I have already had occasion to remark, that the affluents of the Po, on the right bank, are neither very abundant, nor very certain in the volumes of water they carry. Notwithstanding these objections, however, they have been turned to good account for agricultural purposes, to a very considerable extent. Indeed, so valuable is water found to be in the higher regions of this part of Piedmont, that scarcely a mountain torrent is allowed to carry its waters uselessly to the great receiving stream. Canals of various dimensions, ranging from the diminutive channel of three or four, to the considerable canal of fifteen or

twenty feet in breadth, distribute the fertilising waters over the many rich valleys which lie between the mountain ridges, and enable the inhabitants to raise profitable crops of Indian corn, or rice, or other grains. To perfect our view of the canals of irrigation in Piedmont, it is necessary to advert to these works.

It is chiefly in the provinces of Cuneo, Saluzzo, and Pinerolo that the minor streams are employed so largely for irrigation. The rivers supplying the water are the Pellice, the Mellea, the Grana, the Stura, Tanaro, Bormida, and a great number of small torrents, which it is needless to specify. Among the canals, the most important are those of the Stura, Mellea, and Bormida. From the first-mentioned stream are derived :—1st, The Canal of the Stura, executed in 1678, having a length of about nine miles, a mean breadth of 15 feet, and a discharge of about 80 cubic feet per second : it irrigates the districts of Centallo, Murazzo, and Fossano, having its head near the town of Centallo. 2d, The canal di Bra, which is formed by the junction of the canals of the Stura and the Mellea. The latter is derived from the river Mellea, and is one of the oldest canals in the kingdom, having been constructed, first in 1314, by the inhabitants of Fossana, and subsequently enlarged by Emanuel Filiberto, duke of Savoy, in 1569. The length of this canal, before its junction with that of the Stura, is about eight miles, and its mean breadth about 18 feet. The Naviglio di Bra, into which these two channels fall, is in all about twenty miles in length, with a mean breadth of about 20 feet. It commences near Fossano, and flows through the fertile valley of the Stura, irrigating about 5500 acres. It affords a gross revenue of about £650 per annum, and is maintained at an expense not exceeding £100 a-year. The price of water is nearly 3s. 6d. per acre, and the cost

of the canal, or rather of the portion of it lately purchased by government from the proprietors, was a little more than £1000 per mile. 3d, Canal of Pertusata, about 8 miles in length, 15 feet in breadth, having a discharge of 96 cubic feet per second, and irrigating about 4000 acres. It was executed in 1449 by Carlo Emanuel I., and now returns an annual revenue of about £750, at a cost for maintenance of £125. 4th, Canal of Soprano, which has a discharge of about 70 cubic feet per second. The Stura supplies numerous other minor channels, as those of Rovero, Leona, Cherasco, Santa Vittoria, &c., which are of no special importance or interest.

From the Tanaro there is but one important canal, the canal belonging to the Marquis Alfieri, which has the same dimensions generally as the Canal di Bra.

From the Ellero, the Pessio, and the Brebio, affluents of the Tanaro, there are several minor canals, as the canal of Carru, the canal of the Mills, the canals of Montesino and Centallo, with many more.

From the Bormida is derived the modern canal of Charles Albert. This line was originally executed by a company; but as its success was very imperfect, the government purchased it in 1843. I find, on referring to the "*Financial Statement of the Revenue and Expenditure of Piedmont, from* 1830 *to* 1846," published by authority in 1848, that the sum paid for the canal was originally francs 832,830.23, and that a farther sum of francs 180,000 was subsequently expended on various improvements of the line, making the whole cost of the work to the government, francs 1,012,830, or say about £42,000. Its length is 15 miles, its mean breadth 16½ feet, and its depth about 6 feet from the surface of the soil; but it is carried through a very difficult

country, and has some heavy work in retaining-walls, and arrangements for drainage upon it. It is, in its general character, very similar to those canals which the British Government has executed in tracts at the base of the Himmalaya. Its cost (£2800 per mile) has been just about five or six times theirs; and I believe the actual cost to the Company was fully half as much more. The work is considered to be, on the whole, a failure, and seems to have been executed under a singular misconception as to the quantity of water the Bormida could supply, which does not exceed in the irrigating season 80 cubic feet per second. The irrigation on the canal is increasing, but is still very limited, and the revenue is derived chiefly from mill-rent. This revenue amounts to about £1500 a-year, from which about £250 are to be deducted on account of repairs and establishment. The interest on the capital is therefore barely three per cent, and it is never likely, even under the most favourable circumstances, to exceed five per cent. The canal of Charles Albert is no exception to the general rule in Northern Italy, that canals of irrigation, however they may benefit agriculture, are not generally successful as purely financial speculations.

I have before adverted to the canals di Bra and Pertusata, but I may mention, in passing, that I find, from the same financial statement as is above quoted, that government paid for these two lines, including the small canal of Grione, which is fed by springs in the valley of the Stura, the sum of £24,000. Their united length is very nearly 24 miles, so that their cost, including mills and compensation to grantees of the water, was £1000 per mile. I am always glad to get even approximate estimates of the cost of these canals, as it was a species of information I found it very difficult to arrive at.

The price of water on the canal of Charles Albert is rather high, being about 9s. per acre; while on the canals of the Stura, Mellea, &c., it does not exceed 4s. It is, of course, made as high as possible in the former case, to secure some return on the capital; but I have little doubt of the high rate per acre, as compared with the other canals in the same districts, being the main cause of the slow extension of irrigation among the cultivators, for I believe there is no want of land well adapted to the purpose.

In the mountainous parts of the basins of the Dora-Repaira, the Stura (2d), the Orco, and the Dora-Baltea, there is the same general use made of the minor streams draining the small valleys which has been just alluded to as prevailing on the other bank of the Po. The rivers Grandone, Pellice, Chianiogna, Chisone, Lemma, Lungone, the Seconda Gesso, and a network of smaller streams, have all been laid under contribution. On the whole, it is calculated that, within the hilly region of Piedmont, a quantity of water equal to not less than 2500 cubic feet per second is rendered available for purposes of irrigation. The extent of land watered thereby is estimated at 180,000 acres, and by some authorities at considerably more. It is impracticable to offer more than a rough approximation either of the quantity of water, or the areas of irrigation in these rugged tracts, for the first is derived from hundreds of unmeasured sources, and the last are scattered over hundreds of separate valleys. But the data given above do not err, I believe, on the side of exaggeration.*

* M. Nadault de Buffon estimates the quantity of water at 250 "*Ruote*" of Piedmont, equal to nearly 2945 cubic feet per second, and the total area of irrigation at 225,000 acres, being about 77 acres for each cubic foot of discharge. It strikes me this estimate is too high, and I have preferred that given above.

It will doubtless have been observed that, throughout the whole of the details of the system of irrigation in Piedmont now given, I have avoided all reference to the special measures of water employed in that country. The standard measure I have employed has been the discharge per second in cubic feet, and as this varies in each of the Piedmontese measures, I have had much labour in making the necessary reductions. I do not think it expedient to enter upon any detailed explanations on this point here, as hereafter I must collect into a single chapter all the information I have obtained regarding measures of water; but I may mention, in concluding this section, that since the promulgation of the code of Charles Albert, all the ancient measures, no two of which had any precise relation to each other, have ceased and determined in favour of the new *modulo* established by Art. 643 of the code above referred to, the value of which, according to the formula approved by authority, is 2.04 cubic feet per second. This is the standard for all *new* grants of water, though for old ones the original measures remain in force; and I have employed the equivalents of these in English measures in all the reductions I have found it necessary to make in the preceding pages.

SECTION LAST.

GENERAL SUMMARY OF THE IRRIGATION SYSTEM OF PIEDMONT.

It will terminate appropriately the account now given of the canals of irrigation in Piedmont, to present in a summary form the general results exhibited by it, so as to

bring under notice at once a comprehensive view of the entire question.

I have already roughly estimated the area of the irrigated region at about 1½ millions of acres. It may be more satisfactory, however, to give this in greater detail, and to that end I have made use of the data attached to the reduction of the great map of the Sardinian States, executed by the Etat-Major of the army, and published at Turin in 1841.*

From this source, I find the superficial area of the low country in the different irrigated provinces to be as follows :—

	Square miles.		Acres, 640 to 1 sq. mile.
Turin, ...	652	=	417,280
Ivrea, ...	102	=	65,280
Vercelli, ...	531	=	339,840
Novara, ...	324	=	207,360
Mortara, ...	478	=	305,920
Total area of irrigated plain,			1,335,680

As in India, so in Piedmont, it is considered that a deduction of about one-third from the total area for land lost to cultivation, by being occupied as sites of towns and villages, beds of rivers or lakes, marshes, wastes, &c., will leave a fair approximation to the area which is either cultivated or culturable. Such area, in the present instance, would therefore amount to 890,454 acres.

The following statement shows the separate portions of the plain which are actually irrigated :—

* Under the title "Carte degli Stati di Sua Maesta Sarda in Terra Firma opera del Real Corpo di Stato Maggiore Generale incisa e publicata in Anno 1841." This is a reduction in 5 sheets of the great map in 96.

1. Between the rivers Dora-Repaira and Dora-Baltea, . .	19,855
2. Between the rivers Dora-Baltea and Sesia, . . .	121,250
3. Between the rivers Sesia and Ticino, ...	165,508
Total irrigation in the plain, . .	306,613
Add—	
Total of irrigation scattered through the valleys of Upper Piedmont, ...	180,000
Total of irrigation in Piedmont, .	486,613

It therefore appears, that, viewing the irrigated plain as a whole, it is irrigated to the extent of nearly one-third of its cultivated and culturable area—a proportion which certainly indicates a satisfactory state of agricultural prosperity, though it leaves a considerable margin for the extension of the system. In the best organised farms of the plains, where rice, water meadows, and Indian corn are cultivated as irrigated crops, it is considered a properly adjusted proportion to have three-fourths of the land under irrigation, and one-fourth under dry cultivation. The data just given will show that at present this proportion has not yet been reached, since, on the average, one-third only of the land is irrigated, while two-thirds are either under dry cultivation, or, though culturable, are not yet brought into beneficial employment at all.

In that portion of the great plain formed by the low-lying parts of the provinces of Ivrea and Vercelli, and having an irrigable area of about 270,000 acres, we find the actual irrigation extends over 121,250 acres, or a little less than one-half of the entire surface. Again, in the provinces of Novara and Mortara, where the irrigable area amounts to about 342,000 acres, we find the same proportion hold good. The general results, therefore, prove that in these tracts there is a closer approximation to the relative proportion between irrigated and unirrigated cultivation, which is held to be the best; and if that

noble canal from the Po, to which I have before alluded, is ever executed, as I trust it may be, not only to add new channels to those now existing, but to insure more abundant supplies to those lines which at present languish so much under the want of them, there will then be little left to desire in the action of the irrigation system of this region.

The total quantity of water utilised throughout Piedmont is as follows :—

	Cubic feet per second.
1. From the Dora-Repaira, Stura, and Orco, . .	769.05
2. From the Dora-Baltea, ...	2600.00
3. From the Sesia, ...	1003.42
4. From the Ticino and springs, ...	1417.62
5. In the upper valleys, ...	2500.00
Total cubic feet per second, . . .	8290.54

The addition to the rental of land through the country, due to the existence of the means of irrigation, may be estimated approximately at a little more than £290,000 per annum, while the direct returns from the canals themselves may be calculated at about £25,000 annually, of which fully four-fifths appertain to the state, and the remainder to private parties. It must not be overlooked that this amount is far beneath the proper return for the waters, but the numerous gratuitous grants which have been made during the lapse of five centuries have reduced greatly the income derivable from the canals.

When all the canals and their branches are taken into account, we find the irrigated region covered by a network of channels whose united length exceeds 1200 miles; and this does not include the numerous small distributing lines which are to be met with on every farm, nor the channels of the upper valleys. These latter I cannot attempt even to guess at, so numerous are they,

and at the same time so scattered. Most liberal arrangements for cross-communication are made in every part of the country; and it is surprising to the visitor to see the profusion with which works of all kinds have been constructed.

In the course of this sketch I have not hesitated to express frankly my opinion on the works of the canal-engineers of Piedmont, even when these were unfavourable; but I must say that no one familiar with works of irrigation could visit the region over which we have now travelled, without finding much to interest, and not a little to instruct him.

If inferior, as unquestionably they are, both in magnitude and design, to those great works in the plains of Lombardy, to the examination of which we have now to proceed, there can be no hesitation in stating that the irrigation canals of Piedmont are creditable to their constructors, and, as we have abundantly shown, of the very highest value to the agriculture of the regions through which they flow.

CHAPTER II.

CANALS OF IRRIGATION IN LOMBARDY.

SECTION I.

HYDROGRAPHY—SOIL—CLIMATE—POPULATION OF THE IRRIGATED DISTRICTS OF LOMBARDY.

In the introductory remarks to Part II., I took occasion to advert to that happy combination of physical features which has so specially adapted the plain of Lombardy to benefit by the abundant provision nature has made for the development within it of a very perfect, perhaps the most perfect possible, system of artificial irrigation. I drew attention to the great extent of snow-covered mountains which formed its northern boundary, and within which its large rivers had their sources—to that chain of lakes into which these rivers were received before they entered the plain with so much advantage to their ultimate employment as the feeders of irrigating channels, and to the advantageous distribution of the levels of the tracts of country included between the different streams for economising to the utmost the supplies of water they afford. I have now to describe in greater detail this interesting hydrographic arrangement. To this end materials are most abundant, and the great

difficulty is to make a perfectly satisfactory selection among them. Feelings of national pride in the great works which mark the progress of irrigation in this region have co-operated with, and quickened the sense of, their social value, and have led many authors to dwell with what some might consider a wearisome minuteness on all the points connected with their history and development. Of this, however, the stranger visiting the country, and seeking for information, will have but little disposition to complain; and if it entails some additional labour, it throws light upon many points which authors less personally interested in their subject would pass by as unworthy of notice. I give below a summary of the authorities* whence the subsequent information has chiefly been derived; and I may add, that I took every opportunity, during my travels through the country, of verifying, whenever practicable, or, if possible, of adding to, the details I found recorded in the various works referred to.

It is to the lakes of Lombardy, as the most peculiar feature of its hydrography in connection with irrigation, that we have first to advert; and in doing so, the same order of succession will be observed as in the previous chapter.

Commencing, therefore, at the western extremity of the district, the first of the series is the Lago Maggiore, or Verbano, of which the Ticino is the escape-line.

* Bruschetti—"Storia dei Progetti e delle opere per l'Irrigazione del Milanese," published at Lugano in 1834. The same author—"Istoria dei Progetti e delle opere per la Navigazione Interna del Milanese," Milan, 1821.

Cattaneo, Lombardini, Krentzlin, in the "Notizie Civili e Naturali su la Lombardia," Milan, 1844. Cattaneo — "D'alcune Instituzioni Agrarie dell' Alta Italie," &c., Milan, 1847.

"Milano e il Suo Territorio," Milan, 1844.

Lecchi—"Relazione dello Stato Presente del Canale Muzza," Milan, 1760.

"Statuti di Milano," 1775.

The Lago Maggiore is about 40 miles in length, with a maximum breadth of 5½, and a mean breadth of nearly 2 miles. Its superficial area is estimated by Signor Elia Lombardini at 77 square miles, or 47,280 acres. Its elevation above the level of the sea is 638.3 feet; its maximum depth is estimated at no less than 2624.64 feet. It is to this vast depth that the constancy of its surface-level is due, notwithstanding the masses of earthy or stony materials which have been poured into it since its first formation, by the various streams entering it from the surrounding mountains. Not only is the Lago Maggiore the grand receiving basin of the drainage of the adjoining Alpine chain, but several other smaller lakes to the eastward pour their surplus waters into it. Among these, the principal is the lake of Lugano, which, fed by the streams flowing through the valleys of Italian Switzerland, discharges itself by means of the river Tresa into the Lago Maggiore. The lake of Lugano, or Ceresio, is situated at a height of 893 feet above the level of the sea. Its maximum length is nearly 28 miles; its breadth varies from ⅝ths to 2 miles; and its superficial area is about 12,800 acres. Its greatest depth is 520 feet. A little to the southward of Lugano, the lakes of the Varese are linked with the main basin by means of the small streams Bardello and Aquanegra. The most important of this minor series are the lakes of Varese and Canabio. The former is 772.4 feet above the level of the sea; its length is 5 miles; its mean breadth about 1 mile; its area 3840 acres; and its maximum depth about 85 feet. The latter is 736.78 feet above the level of the sea; its length is 2½ miles, and its mean breadth ¾ths of a mile; its area about 960 acres, and its maximum depth 35 feet.

The rivers which flow directly into the Lago Maggiore are, 1st, the Toccia, an important stream, which drains

the Val d'Ossola and its numerous subordinate valleys, receiving also the surplus waters of the Lago d'Orta in Piedmont. 2d, The Maggia, a river of considerable volume, collecting the drainage of the Val Maggia. 3d, The main river of the series, the Ticino, which, on issuing again from the lake, retains its name, and becomes the discharging channel for the whole of the mountain drainage between Monte Rosa and the Splugen. An immense number of smaller channels—one, in fact, for every lateral branch of the great river-valley—carry their waters into the main stream. The drainage of the minor valleys Agno, Colla, Cavargna, &c., is received into the lake of Lugano, and, as before noted, passes by the river Tresa into the Lago Maggiore.

Viewing, accordingly, this great system of mountain drainage as a whole, we find it extending over an area of about 90 miles in length, with a mean breadth of from 25 to 30, or nearly 2500 square miles. Within this area are included some of the loftiest peaks in the Alpine chain, and among them the familiar names of Monte Rosa, Cervino, St Gothard, the Great St Bernard, and the Splugen. Its main arteries, so to speak, are the rivers Toccia, Maggia, and Ticino; and its grand basin is the Lago Maggiore.

As the receptacle of the waters of so extensive a region, the lake is necessarily subject to occasional floods; and at intervals, happily distant from each other, these are truly terrible in their effects. The greatest fall of the surface-level of the water below its ordinary height, in times of extreme dryness, has been noted as 5.76 feet. The floods to which, in spring and autumn, the lake is subject, rise generally about 7 feet above the ordinary level of the surface, while the extraordinary floods exceed 20 feet in height above the same line. There is, indeed, record pre-

served of a flood in the autumn of 1178, which rose 35.36 feet above low-water mark, and caused, in its progress through the low country, an amount of destruction which left, for long years afterwards, distressing memorials of its force and extent. After one of these great floods, it is usual for from fifteen to twenty days to elapse before the surface of the lake returns to its usual level.

Continuing our progress further to the westward, we reach the lake of Como, the next important member of the lake series of Lombardy.

The lake of Como, or—as it is sometimes called from its classic name—the Lario, is 656.75 feet above the level of the sea. Its length is about 50 miles; its maximum breadth $2\frac{3}{4}$; its mean breadth nearly 1 mile; and its perimeter $110\frac{1}{2}$ miles. Its superficial area is estimated at 34,944 acres, and its maximum depth at 1928.7 feet. The lines of mountain drainage which discharge themselves into this basin are the rivers Mera and Liro, which in the first instance fall into the small lake of Mezzola, originally a portion of that of Como, but now separated from it by the alluvial deposits of the Adda. This river, draining the extensive Val-Tellina, is itself the principal feeder of the lake. About midway in its length the lake divides into two branches—one in the direction of Como, the other in that of Lecco, at which latter point the discharging line of the Adda has its origin. Between these two branches there is a tongue of land covered by hills of considerable height, among which the river Lambro rises; and about the centre of the district, in a valley called Pian-d'Erba, there is a group of small lakes—Alserio, Pusiano, Sala, &c.—whereof one is connected with the main basin, while three others are drained by the Lambro. Of this small series of lakes two only are worth adverting to—those of Pusiano and Oggionno.

The former is 850.1 feet above the level of the sea, 2½ miles long, 1 mile broad, with an area of 1664 acres, and a maximum depth of nearly 100 feet. The latter is 740 feet above the sea-level, 2¼ miles long, 1¼ broad, covering an area of 1728 acres, and having a maximum depth of 50 feet.

As the extent of mountainous country which is drained into it is so much smaller, the floods of the lake of Como are inferior to those of Maggiore, both in depth and duration. The low-water mark falls only 3.84 feet below the ordinary surface-level of the water; the usual floods rise 8.74 feet above low-water mark, or 4.9 above the general level; while the extraordinary floods ascend to 13½ feet above the former, or about 10 feet above the latter line. These heights, however, are found sufficient, from local circumstances, to cause serious damage; and as the bed of the Adda is much impeded by alluvial deposits below Lecco, the free escape of the flood-waters is much checked, and the towns on the banks of the lake—especially Como—are subject to inundation. Since 1837, remedial measures have been in progress for improving the bed of the discharging stream, though, I must add, not yet with much effect.

The total superficial area drained into the lake of Como amounts to 1725 square miles; and, owing to the difficulty experienced by the collected waters in escaping from the basin, the influence of great floods is felt for thirty days.

The third of the great lakes we have to notice is, the Lago d'Iseo or Sebino, which receives through the Oglio the whole of the drainage of the great Val-Camònica, and of the two minor valleys of Scalve and Clusone. The Oglio retains its name on issuing from the lake, and becomes its escape-line.

The Lago d'Iseo is 629 feet above the level of the sea; its length is 15½ miles; its maximum and mean breadths are respectively 3½ and 1½ miles; its perimeter 34¾ miles, and its superficial area 14,720 acres. The miximum depth of the basin is 984 feet, and it is divided from the valleys of the Adda, the Adige, and the Mincio, by what Lombard geographers term the Orobian and Camonian mountains. Though the latter contain considerable reservoirs of ice and snow, yet, being protected from the moist sea-winds, they do not cause sudden or excessive floods in the lake—hence the fluctuations of level are moderate. The low-water mark descends only 2.56 feet below the ordinary level of the water. The spring and autumn floods, under ordinary circumstances, rise 5.88 feet above low water, or little more than 3 feet above the usual surface-level, while the greatest floods do not pass the latter line by more than 6½ feet. About the middle of the lake the banks lie low, and hence, even with moderate floods, are liable to be overflowed. The improvement of the line of discharge would unluckily interfere with a considerable extent of irrigation supplied from it; and the interests concerned in this have been sufficiently powerful hitherto to prevent any efficient measures being taken.

In the immediate vicinity of the Lago d'Iseo is the small lake of Spinone or Endine, from which issues the river Cherio, a tributary of the Oglio. It is situated in the Val-Cavallina; is about 3½ miles long, and a quarter of a mile broad, with an area of nearly 640 acres. Farther to the eastward occurs another small sheet of water, the Lago d'Idro, whence flows the river Chiese or Clisio, another affluent of the Oglio. This lake is situated in the Val-Sabbia, at a height of 1241 feet above the level of the sea. Its length is 6, and its mean breadth 1 mile,

containing 3456 acres, and having a maximum depth of 400 feet.

The last and the largest of the great lakes which are linked with the Irrigation System of Lombardy is the Lago di Garda or Benaco. It is supplied chiefly by the river Sarca, which has its origin among the snows of Monte Adamo, and by the streams Ponale and Toscolano, which drain the minor valleys of Ledro and Vesta. It is situated at a height of 226 feet above the level of the sea. Its length is 32½, and its maximum and mean breadths are respectively 10¼ and 4¼ miles. Its perimeter is 87 miles, and its superficial area is estimated at 73,856 acres. Its maximum depth is 1915.59 feet, and the fluctuations of its surface-level are extremely small, owing to its great extent, and to the comparatively limited mountainous area it drains, which amounts only to 786 square miles. The extreme fall of the surface-level in times of the greatest dryness is only 1.64 feet; the usual floods rise only 3.28 feet above low-water mark, or 1.64 feet above the ordinary level of the water; while maximum floods have not surpassed the last-mentioned line by more than 2.36 feet.

Such are the principal details of that invaluable lake-system which we are in the habit of thinking of rather in its relations to the beautiful or the grand in nature, than to the useful in every-day life. Yet, in travelling through the magnificent scenery which distinguishes the region in which these vast basins are found, I do not think the perception of its exquisite beauty, or the feeling of its imposing grandeur, will be deadened by the utilitarian reflection that the whole great masses of mountain and lake are linked together as the most important elements of that hydraulic machinery on which the busy scene of agricultural life and progress, in the rich plains

below, is essentially dependent. The thought will rather add a new feature of interest to the others which already centre in this most interesting district.

I have not considered it necessary to advert specially to the immense number of small lakes which are scattered over the tracts lying between or around the chief basins. There are, however, in the Alpine valleys, upwards of a hundred such lakes, each receiving its little turbid and impetuous mountain torrent, and again sending it forth, subdued and purified, to play its humble part in the extensive system of which it is a member. On the beds of some of these minor basins, the operation of that process of natural "colmatage," from the injurious effects of which their vast depths preserve the great lakes, is very perceptible. Some are filled in by continued deposits; others are marshy, or have their depths considerably diminished. But as the fall of the country is excessive, the drainage waters find ready escape-lines; and I have never heard any fears expressed as to the ultimate results of the process. While, indeed, the large basins remain unaffected in their levels—and the most minute and careful observations show no perceptible alteration in their depths, except occasionally at the shallow outlets of the escape-rivers—there is no serious cause for anxiety in the filling in of a few minor ones—an effect which it has taken *at least* 50, and most probably 50 times 50, centuries to produce.

Perhaps the following table of the principal data given in the preceding pages, with a few others, may be useful:—

NUMERICAL DATA illustrative of the LAKE SYSTEM of LOMBARDY.

PRINCIPAL LAKES,	Verbano or Maggiore	Ceresio or Lugano	Lario or Como	Sebino or Iseo	Benaco or Garda
RIVERS OF ESCAPE,	Ticino	Tresa	Adda	Oglio	Mincio
Height above the level of the sea in feet,	638.3	893	656.75	629	226
Length in miles,	40	28	50	15½	32¼
Maximum breadth in do.,	5½	2	2¾	3½	10¼
Mean do. in do.,	2	¾	1	1½	4¼
Superficial area in acres,	47,280	12,800	34,944	14,720	73,856
Perimeter in miles,	91	54½	110½	34¾	87
Maximum depth in feet,	2624.64	520	1928.7	984	1915.59
Height above low-water mark: of ordinary surface-level:—feet,	5.76	2.65	3.84	2.56	1.64
Height above low-water mark: of ordinary floods:—feet,	13.12	6.06	8.74	5.88	3.28
Height above low-water mark: of extraordinary floods:—feet,	20	9.12	13.5	9.06	5.33
Ordinary duration of floods:—days,	20	15	30	15	30

MINOR LAKES,	Varese	Comabio	Eupili or Pusiano	Oggionno	Spinone or Endine	Idro
LOCAL POSITION,	Near Varese	Near Varese	Pian d'Erba	Pian d'Erba	Val-Cavallina	Val-Salbia
RIVERS OF ESCAPE,	Bardello	..	Lambro	Ritorto	Cherio	Clisio or Chiese
Height above sea-level:—feet,	772.4	786.8	850.1	740	..	1241
Length in miles,	5	2½	2½	2¼	3½	6
Mean breadth in do.,	1	¾	1	1¼	½	1
Area in acres,	3840	960	1664	1728	640	3456
Maximum depth in feet,	85	35	100	50	..	400
Height above low water: of ordy. surface-level:—ft.	1.76	1.44	1.60	1.28	0.64	1.92
Height above low water: of floods:—feet,	5.84	4.56	4.88	4.24	1.92	6.56

From the lakes we proceed in natural order to the rivers of Lombardy; and I will now give as rapid a sketch as possible of their characteristic details, in so far as these are connected with the irrigation system of the country.

The first and most important is the Ticino, the escape-line of the Lago Maggiore, and the present frontier boundary between Piedmont and Lombardy.

This river has its sources in the heart of the Alpine chain, among the vast valleys and ravines which adjoin the St Gothard. Before entering the lake, however, the Ticino is merely one of several streams of nearly equal importance. It is on issuing from the lower extremity of the vast basin, and becoming the sole discharging line of the great volume of water drawn from the mountains, that it becomes a river of the first class. From Sesto Kalende, its head, to Tornavento, where the Naviglio Grande leaves it, the stream flows within deep banks of gravel, clay, or boulders, disposed in steps, and ranging from 15 to as much as 150 feet in height. The current is here rapid, and the channel clear of deposits or other impediments—a result due to its rapid slope and limited breadth. Below Tornavento the channel widens much; alluvial deposits occur, and form islands within the stream. To illustrate the distribution of the slope of the river, I give the following details :—

	Distance in miles.	Total fall in feet.	Slope per mile in feet.
Sesto Kalende, ...	0.00	0.00	0.00
Tornavento, head of the Naviglio Grande, .	14.41	146.91	10.2
Bridge of Buffalora, ...	13.98	118.11	8.4
Junction of the canal of Pavia, . . .	29.07	177.48	6.1
Junction with the Po, ...	4.34	5.24	1.2
Totals, . . .	61.80	447.74	7.2

With a general rate of slope so considerable as is here shown, it is natural to conclude that the upward navigation of the river must be almost impracticable, owing to the rapidity of the current. Hence it is that the construction of that series of navigable canals, which, com-

mencing at Tornavento, and terminating at the point of junction of the canal of Pavia, only about four miles from the mouth of the Ticino, has proved of such immense value to the country. But for it, the water-communication by the river must have ever been of the most precarious and tedious character.

From Sesto Kalende to Pavia, the Ticino does not receive a single important tributary. Its volume is therefore formed almost entirely from the drainage of the mountain region, whose limits I have already indicated as including nearly 2500 square miles. The entire area, embracing the low as well as the high country, is thus distributed :—

	Square miles.
Mountainous region, . . .	2412
Low country, ...	293
Total area of basin,	2705

Although the discharge necessarily varies much at different seasons, and data are not very precise as to its actual amount, I find that, under ordinary and average circumstances, it is estimated at 11,667.55 cubic feet per second. Of this quantity, between one-fourth and one-fifth, or nearly 2550 cubic feet per second, are utilised for purposes of irrigation on both banks, and the remainder constitutes the ordinary volume of the stream. I may mention here, that the singular and interesting phenomenon of percolation, which is so marked in the beds of the Himmalayan rivers of India, is not less strikingly shown in those of Northern Italy. In seasons of great dryness, the entire volumes of the Ticino and other irrigating rivers have at times been entirely exhausted to meet the demands of the cultivators. The results are thus adverted to by M. Lombardini, a minute and accurate observer,

who has devoted himself especially to the study of river phenomena :—" The subterranean waters with which the plain is charged are also occasionally collected in the rivers, whose beds are below the level of the ground. These streams, exhausted in their upper portions by the channels of irrigation derived from them, are found to become gradually refilled at lower levels with new waters. The Ticino, at Tornavento ; the Adda, at Cassano ; and the Oglio, at Torre Pallavicina, in times of great dryness, are entirely closed and exhausted. Yet, without the aid of any visible affluent whatever, the streams soon re-appear, formed by new supplies derived from percolation through the banks and springs in the beds, so that they early again become navigable." This is precisely the result observed in Northern India, and with which the main objection urged against the grand Granges Canal, that it will ruin the navigation of the river, has hitherto been combated. I am glad to be able to bring Italian as well as Indian experience to the support of this work, beside which even the greatest of the Lombardian canals appear small.

The drainage of the Varese, and of the hilly country in the vicinity of the lake of Como, which is locally termed the Larian Peninsula, is effected by means of a series of small rivers, all of which become linked with, and some of them altogether absorbed in, the irrigation system. Of these, the most westerly, and one of the most important, is the Olona, which, rising among the Monti Varesini, flows within a deep and wide valley to Nerviano, whence it is carried to the walls of Milan, under which it loses its name, and divides its waters among the three canals with which it is there united. The latter portion of the course of this stream has been greatly modified by art, and its ancient channel is now occupied

by another small river, the southern Lambro, which acts as an escape-line for the Naviglio Grande. A stream called the Olona reappears at Binasco, some miles to the southward of Milan, and flows from thence directly to the Po. This, however, is a different line altogether from the Northern Olona, and is usually distinguished from it by being termed the Southern Olona. The Northern Olona, from the bridge of Malinate, near Varese, to its junction with the Grand Canal, is 33 miles in length, with a total fall of 565.90 feet, or very nearly 17 feet per mile—an enormous slope, which gives to this stream all the characteristics of an impetuous mountain-torrent.

The Seveso is another small river of the same class as the preceding, and rising in the same region between Como and Lecco. At a short distance from Milan it falls into the canal Martesana, and is absorbed by it.

The next in order of the minor rivers is the largest of the whole, the Northern Lambro, which, entering the small lake of Pusiano, under the name of the Lambrone, issues from it, after a very short course, and flows between high banks of conglomerate to Canonica. It traverses the park and city of Monza; and near Crescenzago it crosses the bed of the canal Martesana, in the bank of which there is a large masonry escape provided for it. At Meregnano, the Addetta, which forms an escape-line for the canal Muzza, joins it, as does also the Vettabia, which rises near Milan. At St Angelo it is joined by the Southern Lambro, to which reference was formerly made; and the united streams, sometimes within high banks, and sometimes at the level of the ground, pass onwards to the Po. The following details will give an idea of the distribution of the slope of the Northern Lambro :—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Lake of Pusiano, . . .	0.00	0.00	0 00
Monza, ...	19.70	340.56	17.3
Canal Martesana, . . .	11.41	79.38	7.95
Lambrate, ...	2.35	22.24	9.4
Junction of the Addetta, . .	10.80	118.11	10.9
Bridge of Meregnano, . . .	0.70	3.28	4.7
San Columbano, . . .	19.57	91.86	4.7
Junction with the Po, . . .	7.45	20.64	2.7
Totals,	61.98	676.07	10.9

The numerous other small streams, completing the drainage system between the Ticino and the Adda, present no features requiring special note. The whole of them become affluents either of the Olona or the Northern Lambro; and the basins of these two rivers are thus distributed :—

	Square miles.
Mountain region, . . .	91.5
Low country, . . .	1236.
Total area of basins,	1327.5

The combined volume of the two rivers under ordinary circumstances is estimated at 1037.75 cubic feet per second. The whole of the series of rivers to which reference has now been made, have, as common characteristics, excessively rapid slopes in the upper portions of their channels, and a supply of water which is constant; hence they are admirably adapted for industrial purposes, and their beds are studded with mills of every description. Thus, on the small stream Bardello, the escape-line of the Lago Varese, there are thirty-six water-wheels; on the Tresa, twenty-two; and similarly on the rest: so that

the high country through which they first pass presents as busy a scene of manufacturing as the low country does of agricultural activity.

The Indian canal-officer will recognise at once in these streams the leading characteristics of those mountain torrents which are so intimately connected with the Irrigation System with which he is familiar. The torrents of the Sub-Himmalayas,—with their excessive falls, their dangerous but transient floods, their constant intersections of the canal lines, and their troublesome deposits,—find their counterparts in these streams of the Sub-Alpine chain, which, however, are more useful to the community, inasmuch as their supplies rarely fail altogether, and they are less difficult to control, since their volumes never approach, even in extreme circumstances, to those with which we have to deal during the season of periodic rain.

Continuing our progress to the eastward, we next find the second great irrigating river of Lombardy, the Adda, which forms the escape-line of the lake of Como. The first part of its course, from Lecco to Brivio, may be described as lacustrine in its character; and to three separate portions of it the names of the lakes Moggio, Olginate, and Brivio, have been applied. Alluvial deposits, formed by the streams entering on the left bank, cause much inconvenience here, and diminish greatly the efficiency of the river as an escape for the great basin. Southward of Brivio the fall becomes much more rapid; and the channel being bounded by high strong banks, the river loses altogether its lacustrine character, and flows in a single stream with a swift current. None of the rivers of Lombardy have been so minutely observed as the Adda, and a great mass of observations upon it, under all circumstances, and continued for many years, have been recorded. From these it appears that its

average volume amounts to 6539.75 cubic feet per second. In times of maximum floods, the discharge of the river rises to about 28,000 cubic feet per second. It is, however, a remarkable illustration of the influence of the lake-system in modifying and regulating these river floods, to find that, during the great one of September 1829, the quantity of water *entering* the lake of Como was determined, by most minute and careful observation, to reach, during the time between the 15th and 20th September, the enormous volume of 70,000 cubic feet per second; while, at the same time, the greatest quantity *issuing* from the lake was 28,140 cubic feet per second. This maximum of *efflux* was reached *a day and a half* after the maximum of *afflux* above noted. Had no lake existed, the huge mass of 70,000 cubic feet per second would have been poured at once through the channel of the river, with effects on the low country of the most destructive character. Under the happy natural arrangement which actually exists, that volume of water was disposed of gradually, and without serious injury of any kind.

The variations of volume in the Adda are considerable. In times of extreme dryness, it has been known to have only 560 cubic feet per second; but so excessive a diminution is rare; and under ordinary circumstances of heat and dryness, there is supply sufficient for the canals drawn from it, which utilise about 3700 cubic feet per second, or rather more than half the average annual discharge formerly noted.

The following details illustrate the distribution of the fall of the channel, which as far as Cassano is single, but below that point becomes divided into several branches by richly-wooded alluvial islands. From Lodi to the Po the waters are collected into a serpentine channel of moderate declivity, and navigable without difficulty.

LEVELS OF THE ADDA.

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Lake of Como—Pescarino,	0.00	0.00	0.00
Bridge of Lecco,	0.42	0.34	0.57
Lake of Moggio—Pescalino,	0.80	1.82	2.27
Capella di Olginate,	2.22	0.00	0.00
Lake of Olginate—Rondo d'Adda,	0.30	1.18	3.93
Santa Maria di Lavello,	0.74	0.24	0.32
Lake of Brivio—Bridge of Capiate,	0.68	4.56	6.70
Dam of Brivio,	3.84	1.98	0.50
Soldato,	0.62	5.52	8.90
Sill or Inlet of the Canal of Paderno,	4.08	39.69	9.91
Junction of do.,	1.54	89.50	58.01
Rondinera,	1.10	7.20	6.54
Trezzo—mouth of the Canal Martesana,	4.46	35.36	7.92
Fall of Dam of do.,	...	5.29	5.29
Junction of the River Brembo,	1.66	15.87	9.56
Canonica,	0.80	7.20	9.00
Cassano—head of the Canal Muzza,	4.02	34.81	8.65
Fall of Dam of do.,	...	6.68	6.68
Corneliano,	4.34	45.93	10.58
Buffulora,	10.86	97.54	8.98
Lodi,	2.90	15.36	5.29
Cavanago,	11.04	40.65	3.68
Junction of the River Serio,	8.69	32.38	3.72
Junction of the Canal Muzza,	3.40	8.96	2.63
Castiglione Lodigiano,	0.92	2.14	2.32
Pizzighettone,	8.37	17.68	2.11
Crotta d'Adda,	5.77	12.08	2.09
Junction with the Po,	3.84	8.09	2.10
	88.31	605.95	6.86

The basin of the Adda is distributed as shown below :—

	Square miles.
Mountainous region,	1725
Low country,	539
Total area of basin,	2264

I have already mentioned that the average volume of the Adda is 6539.75. A small additional supply is furnished from the minor drainage of the plain, which is estimated at 392.70 cubic feet per second. The entire discharge of the river is, therefore, 6932.45 cubic feet per second.

The Adda receives only two tributaries of importance: the Brembo, which issues from the valley of the same name, and joins the Adda after a course of about 35 miles; and the Serio, which, rising in the same tract of country, joins the main river after a course of about 60 miles. These two lines collect the drainage waters of the hilly country on the left bank of the Adda, and the areas of their respective basins are distributed as follow :—

	Square miles.
Brembo—Mountainous region, . . .	294
Plain, ...	46
Total area of basin, . .	340
Serio—Mountainous region, . . .	220
Plain, ...	246
Total area of basin, . .	466

Their volumes are respectively 836.85 and 782.25 cubic feet per second. The average discharge of the entire drainage system, of which the Adda is the chief, and the Brembo and the Serio the most important subordinate channels, amounts, therefore, to 8551.55 cubic feet per second.

The levels of the beds of the two rivers are shown in a condensed form below :—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Brembo—			
Lago del Diavolo, ...	0.00	0.00	0.00
Almenno, ...	26.71	1692.49	63.3
Ponte San Pietro, ...	4.03	149.24	37.0
Junction with the Adda, . . .	8.99	271.91	30.2
Totals, . . .	39.73	2113.64	53.2

A glance at these numbers explains in a moment the observed fact, that, after the junction of the Brembo, the Adda loses that clearness for which its waters were before remarkable. With such a volume, and such a fall per mile, as the former river is shown to have, its erosive power must be enormous; and it is, in fact, always charged with a very large proportion of earthy matter.

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Serio—			
Lago Barbellino, . . .	0.00	0.00	0.00
Olzano Maggiore, . . .	31.99	1858.13	58.08
Seriate, ...	3.10	82.02	26.40
Bettola, near Mozzanico, . .	14.59	254.22	17.4
Crema, ...	9.32	111.55	11.9
Montodine, ...	6.21	49.85	8.0
Junction with the Adda, . .	3.10	19.68	6.3
Totals, . .	68.31	2375.45	34.7

The same excessive slope in the Serio leads to the same effect on the waters of the Adda, as in the case of the Brembo; and, by the influence of the two rivers with that of the torrents of Albenza and Resegone, the deposits of the Adda become seriously injurious to its utility for agricultural purposes, as they are not of a fertilising character.

The Oglio, the discharge-line of the Lago d' Iseo, is the next in order of the larger rivers we have to advert to. On issuing from the lake, it flows within a deep valley, having banks rising in picturesque steps to a height of from 120 to 150 feet, and formed by sandy gravel, or other similarly friable materials. In its progress through the plain, the height of its banks gradually decreases, till

they do not rise more than a few feet above the level of the water.

Its levels are thus distributed:—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Lago d'Iseo, Sarnico, . .	0.00	0.00	0.00
Palazzolo, . . .	6.83	97.70	14.3
Pontollio, . . .	3.34	42.44	12.7
Rocca Franca, . . .	9.62	116.75	12.1
Soncino, . . .	4.88	54.41	11.1
Bordolano, . . .	11.18	94.38	8.4
Ponte Vico, . . .	7.45	49.21	6.6
Junction of the Mella, . .	6.51	38.32	5.8
Canneto, . . .	12.54	37.04	2.9
Junction of the Clisio, . .	4.46	12.72	2.8
Do. with the Po, . .	21.74	29.84	1.3
Totals, . .	88.55	542.81	6.1

The area of the basin of the Oglio is given below :—

	Square miles.
Mountainous region, ...	736
Plain, ...	768
Total area of basin, ...	1504

The average volume of the river, including the small tributaries carrying the drainage water of the plain, is estimated at 2975.35 cubic feet per second.

On the right bank, the Oglio receives a single tributary of no great importance, the river Cherio ; on the left it is joined by the Strone near Ponte Vico, the Mella above Ostiano, and the Clisio below Canneto. Of these streams the Mella and the Clisio only require any detailed notice.

The Mella, rising in the Val-Trumpia, in the vicinity of Brescia, flows generally at the level of the surface, though, towards the latter portion of its course, its channel becomes much deepened. Its general inclination is thus shown:—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Travata Pellegrini,	0.00	0.00	0.00
Fiumicello,	1.79	69.53	38.8
Roncadelle,	1.36	42.25	31.0
Ponte Gattello,	5.15	83.30	16.1
Manerbio,	9.44	123.31	13.0
Pavone,	5.65	45.93	8.1
Junction with the Oglio,	6.76	46.05	6.8
Totals,	30.15	410.37	13.6

The basin of the Mella has the area shown below :—

	Square miles.
Mountainous region,	158
Plain,	279
Total area of basin,	437

and the average discharge of the river is estimated at 592.55 cubic feet per second.

The Clisio is the escape-line of the Lago d'Idro, in the Val-Sabbia, and flows in a deep valley through the table-land of Montechiaro.

On leaving this steppe, its channel is but little depressed beneath the general surface of the country until it reaches Asolo, when it is again bounded by lofty banks, chiefly on the left. Its levels are as follow :—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Lago d'Idro,	0.00	0.00	0.00
Lavenone,	1.08	107.22	99.2
Vestone,	2.72	81.30	29.6
Nossa,	1.10	25.48	23.1
Barghe,	2.28	55.37	24.3
Sabbio,	1.66	52.09	31.4
Vobarno,	4.76	111.55	23.4
Gavardo,	6.13	135.79	22.1
Bridge above Montechiaro,	15.65	331.36	21.1
Junction with the Oglio,	22.36	250.30	11.2
Totals,	57.74	950.46	16.4

The basin of the Clisio is thus distributed :—

	Square miles.
Mountainous region, ...	423
Plain, ...	189
Total area of basin, . . .	613

The discharge of the river, including the small subtributaries connected with it, is estimated at 1291.50 cubic feet per second. Hence it appears that the entire system of the Oglio and its branches drains an area of 2553 square miles, and has a total discharge of 4859.40 cubic feet per second.

The last of the great rivers of Lombardy which may be considered to form part of its irrigation system, is the Mincio, the escape-line of the Lago di Garda. On issuing from the lake at Peschiera, it flows with a very gentle slope to Saliunce, whence its fall increases rapidly, and its velocity becomes great. It is bounded by beautiful tracts of hilly country, and is confined within lofty banks of sand and gravel. Below Goito, its inclination diminishes greatly, and it begins to form stagnant sheets of water. In the immediate vicinity of Mantua it spreads into a series of lakes, which constitute most important elements in the defences of that great fortress. The Lago Superiore, as that to the northward of the city is called, was much extended by the construction, about the close of the twelfth century, of the Ponte dei Molini, and two other dams, which retain the water, and cause it to extend over the adjoining low-lands. The Lago Inferiore, part of which is termed the Lago di Mezzo, is formed by the dam of Governolo, constructed at about the same time as those above referred to. The Lago Superiore, which is the most important, is 63.93 feet above the level of the sea. Its length is 4.58 miles—its breadth about half a mile—its area 1280 acres—and its

maximum depth 27.84 feet. Boats frequent the lakes, and are passed into the lower channel of the river through a lock in the dam of Governolo, constructed at the beginning of the sixteenth century. Below the lakes, the Mincio flows either at the level of the country or within embankments.

The fall of the channel is distributed as shown below:—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Lago di Garda and Peschiera,	0.00	0.00	0.00
Saliunce,	2.23	2.84	1.2
Fall,	...	1.53	0.0
Monzambano,	1.98	10.48	5.3
Valleggio,	2.79	7.71	2.8
Fall,	...	3.04	0.0
Molini della Volta,	3.72	29.12	7.8
Fall,	...	4.71	0.0
Massimbona,	2.28	21.60	9.4
Bridge of Goito,	3.28	38.83	11.9
Lago Superiore,	8.99	42.65	4.7
Lago di Mezzo and Inferiore,	4.64	...	0.0
Fall of the Ponte dei Molini,	...	15.34	0.0
Piètole,	3.96	...	0.0
Formigosa,	1.72	0.24	0.1
Governolo,	8.07	2.40	0.3
Fall of the Conca,	...	1.08	0.0
Junction with the Po,	1.86	0.38	0.2
Totals,	45.52	481.95	3.9

From these numbers it is evident how very irregularly the slope of the Mincio is distributed, and how very much inferior it is to those of the rivers with which we have hitherto had to do. The area it drains is thus distributed:—

	Square miles.
Mountainous region,	786
Plain,	313
Total area of basin,	1099

The average discharge of the river is estimated at 2658.95. The influence of the great basin from which it issues in regulating its floods is very perceptible; for

while those of the Oglio, flowing from the comparatively small lake of Iseo, reach upwards of 19,000 cubic feet per second, or nearly four times the average supply, those of the Mincio are never more than 5250 cubic feet, or barely twice the average volume of the stream.

The river Adige may be held to be the real boundary of the irrigated plain of Northern Italy, for to the eastward of this stream the waters are employed for agricultural purposes to a very limited extent. It is only, therefore, necessary for me to state now, that between the Mincio and the Adige there are a number of small rivers, among which the chief are the Tione, the Tartaro, the Tregnone, the Minago, and the Busse, all of which are laid under contribution for purposes of irrigation.

The region whose hydrographic details have now been completed is lancet-shaped in its general outline, Quattrelle on the Po being regarded as its point. One long side is formed by a line following the general direction of the river Po from Quattrelle to Pavia. From Pavia to the highlands of Somma we have a short side, which nearly coincides with the river Ticino. From Somma, along the hills of Como and the Upper Milanese, we have a third side, which terminates at Bergamo; and the circuit is completed by the long line which stretches from Bergamo along the Brescian and Mantuan highlands, and terminates at the starting-point of Quattrelle. This is, of course, a rough tracing of the outlines of the plain, but as an aid to the memory, and a general guide to the eye, it may perhaps be useful. In the distribution of the surface-slope of this tract, on which its irrigating capabilities are so intimately dependent, I may note that, as in the case of the plain of Piedmont, it has a double slope, from north to south, *to* the Po, and from west to east, *with* the Po. The former, which is the slope of

irrigation, is throughout most abundant for every useful purpose, never falling below from 3 to 5 feet per mile, and being generally much more. The latter, which is the slope of drainage, follows the fall of the Po, and is comparatively gentle, varying from about 2 feet per mile at the mouth of the Ticino to about 6 inches per mile at Quattrelle.

The total area of Lombardy may be estimated approximately at 8200 square miles; and if the Venetian province of Verona, which possesses a considerable extent of irrigation, be added, the result is a total of nearly 9350 square miles; or, in round numbers, little less than 6,000,000 of acres. There is wonderfully little of this vast area which is waste or useless; for I find, on referring to the statistical tables accompanying the large "*Map of the Lombardo-Venetian Kingdom*," published by the Austrian government, that of a total area of 8262 square miles in Lombardy, 561 only are reported as sterile and unproductive, being about one-fourteenth of the whole. The case is different in the only Venetian province we have occasion to advert to, as, of the 947 square miles forming the superficies of Verona, no less than 220, or nearly one-fourth of the whole, are noted as lost to cultivation—a proportion due chiefly to the vast marshes which cover so many parts of this district. When the limits of actual irrigation are hereafter indicated, it will be necessary to return to this point; and I need only further mention here, that while, in all the provinces of Lombardy, the waters are more or less utilised, the grand development of that system of irrigation to which the fame of the country is due takes place within the provinces of Milan, Lodi, and Pavia.

I must not, however, leave the hydrography of Lombardy without adverting for a moment to that rich supply of water which is derived from the springs, or

fontanili, so abundantly met with over the whole surface of the plain. It is not practicable to estimate rigidly the quantity of water supplied from such sources, but experienced authorities calculate it as at least 2000 cubic feet per second; and it is upon this volume that the vast marcite or winter-meadows of the Milanese are almost exclusively dependent.

The following condensed statement will exhibit at a glance the principal sources of supply which have been provided by nature for the irrigation of Lombardy :—

STATEMENT showing AREAS of the BASINS and VOLUMES of the IRRIGATING RIVERS of LOMBARDY.

	Area of basin in square miles.	Volume of water in cubic feet per second.
1. Ticino, ...	2705	11,667.55
2. Adda, ...	2264	6,932.45
3. Brembo, ...	340	836.85
4. Serio, ...	466	782.25
5. Oglio, ...	1504	2,975.35
6. Mella, ...	437	592.55
7. Clisio, ...	612	1,291.50
8. Mincio, ...	1099	2,658.95
9. Small streams, springs, &c., .	...	3,000.00
Totals, .	9427	30,737.45

The soil of Lombardy is similar in its general characteristics to that of Piedmont already described. In the upper portions of the plain it consists of deep beds of gravel overlaid by light sand, and wells sunk through it to a depth exceeding 300 feet show the same uniform section. In the lower portions there are considerable areas of clayey soil, underlaid, however, as before, by a subsoil of pervious gravel or sand, through which the water finds its way with facility. The only great marsh in the Milanese Proper is in the vicinity of Crema, between the Adda and the

Serio. Throughout the province of Mantua the soil is heavy and compact, necessitating the use of drainage as extensively as that of irrigation. In the Veronese it is very stony and light. In a word, the irrigated region is a great alluvial plain, exhibiting the usual varieties of surface-soil found in such formations, and enriched by an abundance of manure derived from the vast quantities of cattle which form the principal elements of its prosperity. I have formerly mentioned, in illustration of this latter point, that within the triangle between Milan, Lodi, and Pavia, it is calculated that there exist not less than 100,000 head of cattle, 25,000 horses, and 100,000 head of smaller stock, as pigs, &c., the whole of the manure supplied by which is applied to the enrichment of the soil.

It has generally been thought that the superiority of the laws and regulations affecting irrigation was the main cause of its remarkable development in Lombardy. It would be out of place to dwell here at any length on the inadequacy of this cause alone to account for the observed effects. The good laws have been, in fact, but one of many co-operating causes—the influence of race, of concentration of capital and property, of the peculiar action of the various governments which at different times have ruled the country, with reference to the disposal of water in absolute property to rich landowners, have all had their share, in combination with the singularly happy physical features of the country, in producing that state of things we now see, and to no one single origin can it with truth and justice be attributed. Among the physical causes, we have yet to notice the climate, which has been scarcely less influential than either the hydrography or the topographical structure of the country.

To admit of a correct general idea of this being formed, I have availed myself of observations made at Milan,

Pavia, Brescia, Bergamo, and Mantua, which embrace a tract of country in the very heart of the irrigated region, and extensive enough for every practical purpose. The thermometric results for Milan are derived from observations continued for 81 years—for Pavia, for 19 years; for Lodi, for 72 years; for Brescia, for 22 years; for Bergamo, for 4 years; and for Mantua, for 13 years. Observations on the fall of rain have been made at the different places noted for like periods. I may further observe, that climate is regarded here solely in its relation to irrigation, and not as a general question at all. Hence the details are restricted to such as are connected with the former subject.

TABLE of TEMPERATURE IN LOMBARDY during the SEASON of IRRIGATION, or from MARCH to SEPTEMBER.

	Milan.			Pavia.			Brescia.		
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
	Faht.	Faht.	Faht.	Faht.			Faht.	Faht.	Faht.
March, ...	44.6	62.4	33.2	47.3	,,	,,	48.4	64.7	32.9
April, ...	54.8	67.6	40.3	55.9	,,	,,	57.0	72.8	40.6
May, ...	64.0	78.1	49.6	65.3	,,	,,	64.4	78.6	48.4
June, ...	70.5	84.0	56.5	74.1	,,	,,	71.0	84.7	55.6
July, ...	74.8	87.2	60.9	78.1	,,	,,	75.0	87.9	59.9
August, ...	71.4	86.5	59.5	75.4	,,	,,	74.1	86.7	59.0
September, ...	66.4	80.0	53.4	66.9	,,	,,	67.1	80.2	54.7
Winter, ...	36.1	53.8	18.3	35.6	,,	,,	39.4	57.9	18.9
Spring, ...	55.0	78.1	33.1	56.1	,,	,,	56.5	78.9	32.7
Summer, ...	72.8	88.5	56.1	75.9	,,	,,	73.7	88.9	54.5
Autumn, ...	56.3	82.6	32.5	55.9	,,	,,	58.1	80.6	33.1

The monthly details for Lodi, Bergamo, and Mantua are not given, but the following show the annual mean temperatures at these places:—

	Mean.	Maximum.	Minimum.
Bergamo, . .	57.4	90.5	18.2
Lodi, . . .	54.5	86.0	16.5
Mantua, . . .	...	91.0	17.5

From these figures it appears that, during the months of

May, June, July, and August, when water is in greatest demand, the mean temperature throughout the irrigated region ranges from about 70° to 75° Fahr., and the maximum from about 85° to 90°. It does not, however, unfrequently happen that the maximum temperature exceeds considerably the higher of these limits—rising at Milan to 94°, at Brescia to 92.8°, at Lodi to 91°, and at Mantua to 98.2° of Fahr. With temperatures such as these, water for the land is a matter of the deepest importance.

The indications of the hygrometer show an extraordinary degree of dryness in the atmosphere of Lombardy during the season of irrigation. The wet-bulb thermometer has been carefully observed at Milan, and with the following results :—

STATEMENT of ATMOSPHERIC MOISTURE in the IRRIGATED REGION of LOMBARDY.

	Mean.	Maximum.	Minimum.
March, . . .	70.08	96.55	15.21
April, . . .	51.73	92.56	2.19
May, . . .	67.71	95.85	19.44
June, . . .	55.33	94.18	1.25
July, . . .	57.93	99.41	2.11
August, . . .	67.04	97.61	4.65
September, . .	65.61	97.88	10.05
Winter, . . .	83.98	99.81	18.66
Spring, . . .	74.95	98.81	5.40
Summer, . . .	63.95	99.41	2.11
Autumn, . . .	77.85	99.24	6.21

During the winter the hygrometer indicates an almost constant state of extreme humidity, approaching closely to total saturation. On the other hand, during the summer months, extreme dryness is the characteristic of the atmosphere, the instrument for days together standing a few degrees only above zero. When it is borne in mind

that during this period not a single day passes but upwards of 30 millions of tons of water are artificially spread over the face of the country, it is certainly remarkable that the result of its evaporation should be so little perceptible. It is always pleasant to me to be able to link my present work with that distant land where I hope yet to labour long; and I cannot pass the present subject by without drawing attention to its bearing on the extension of the irrigation system of India. It was a serious subject of alarm to Government and others, to contemplate the possible results of introducing irrigation over about $1\frac{1}{2}$ millions of acres in Northern India through the means of the Ganges canal. It was said we were about to create a climate so damp as to be wholly incompatible with the habits and the feelings of the population, and to insure all kinds of evils arising among them in consequence thereof. Let the state of Lombardy be considered, and let it be remembered that we have there, in latitude 45°—46°, an extent of irrigation as great as it is proposed to establish in latitude 25°—29°, and I am sure that all such fears as I have above referred to will disappear. I doubt much whether the influence of the whole extent of irrigation to be effected by the Ganges canal will cause the slightest perceptible change in the summer climate of the north-western provinces; and if a slight change is caused, it will far more probably be a beneficial than an injurious one, for a certain increase of humidity in the air, during the intensely dry months of summer, would be a blessing to man and beast, as every one who has felt a genuine "hot wind" in May or June will be ready to admit. But seeing what the sun does in Lombardy, I despair of finding his evaporating power modified (in so far as climate is concerned) by anything the hand of man can do in India.

It only remains now that I should exhibit some data to show the amount of rain and the quantity of sunshine enjoyed by the irrigated region of Lombardy, elements of climate whose importance need not be insisted upon.

STATEMENT of RAIN-FALL and WEATHER in the IRRIGATED REGION of LOMBARDY during the SEASON of IRRIGATION.

	Rain-fall.	Clear days.	Cloudy.	Rainy.
	Inches.			
March, . . .	2.3	17.5	10.1	3.4
April, . . .	3.1	15.9	7.8	6.3
May, . . .	3.8	14.1	15.1	1.8
June, . . .	3.1	19.4	8.8	0.9
July, . . .	2.8	21.7	7.5	0.9
August, . . .	3.2	21.3	8.2	1.5
September, . . .	3.4	17.8	9.3	2.9
Winter, . . .	8.0	42.2	31.5	13.3
Spring, . . .	9.3	47.5	34.7	9.8
Summer, . . .	9.2	62.4	26.3	3.3
Autumn, . . .	11.8	46.8	32.5	11.7
Annual, . . .	38.3	198.9	128.0	38.1

The following show the same results throughout the year for Brescia and Lodi :—

	Annual rain-fall.	Clear days.	Cloudy.	Rainy.
Brescia, .	35.37 inches	239.2	95.3	30.5
Lodi, .	38.18 „	174	...	...

From these data we infer that the average annual amount of rain which falls in the irrigated districts may be taken at nearly 36 inches, of which the large proportion of nearly 22 inches falls during the season of irrigation, being divided over a mean number of 24 rainy days, thus giving a daily fall of 0.91 inches. In Piedmont we found the number of rainy days during the same season to be 71—nearly three times as many as in Lombardy. It is, further, very interesting to note how large is the quantity of sunshine the latter region enjoys. For a little less than half

the year, the sky at Milan is unclouded, and the vegetation receives the unchecked influence of the sun's light and heat. At Lodi the same happy conditions exist for more than half, and at Brescia for two-thirds of the entire year. This state of climate is almost tropical: in Northern India the temperature of the summer is scarcely higher than it is occasionally in Lombardy; the number of bright unclouded days is nearly the same as at Brescia, so that it may appropriately be said of this part of the great valley of the Po, that, though it has a temperate climate on the whole, it has yet a summer resembling, in many material respects, that of the upper valley of the Ganges.

Before concluding this section, I have a few words to say on the distribution of the population of Lombardy. The total population amounts to 2,471,634, according to the latest census to which I have had access. The details of this are not so minute as those given in the census of Piedmont, but the general results are nearly the same, and they show that in the districts of upper Lombardy, where dry cultivation alone is followed, there is a ratio of population considerably superior to that in the most richly irrigated region. The following illustration of this point may be interesting; and in selecting the districts, I have avoided taking those in which the capitals are situated, the ratio of which is affected by the town population:—

[STATEMENT

STATEMENT showing the RATIO of POPULATION to AREA in certain IRRIGATED and UNIRRIGATED Districts of LOMBARDY.

Irrigated.	Population per sq. mile.	Unirrigated.	Population per sq. mile.
1. Abbiategrasso, .	392.5	1. Varese, . .	619.5
2. Bollate, . .	427.5	2. Tradate, . .	447.5
3. Gorgonzola, .	567.5	3. Appiano, . .	462.5
4. Melzo, . .	285.	4. Marriano, . .	582.5
5. Paullo, . .	287.5	5. Verano, . .	542.5
6. Melegnano, .	342.5	6. Messaglia, . .	570.
7. Londriano, . .	360.	7. Brivio, . .	600.
8. St Angelo, . .	487.5	8. Como, . .	430.
9. Pezzighettone, .	342.5	9. Erba, . . .	610.
10. Casal Maggiore, .	460.	10. Oggionna, . .	550.
11. Bozzolo, . .	430.	11. Caprino, . .	582.5
12. Canneto, . .	307.5	12. Conzo, . .	327.5
	4690.0		6324.5
Mean ratio of irrigated districts,	390.8	Mean ratio of unirrigated districts,	527.04

I sought an explanation of the higher ratio of the population in the unirrigated districts, from several Lombard friends, and it was invariably attributed to the prevalence, in Upper Lombardy, of small properties, cultivated exclusively by the proprietors themselves and their families. It was held that the land, so divided and cultivated, supported a denser population than when formed into those large farms which characterise Lower Lombardy. The mountain streams in these high localities furnish a motive force which is employed largely in manufactures of various kinds for internal consumption; and throughout the districts noted in the preceding statement, there are said to be not less than 80,000 looms in the houses of the rustic population, for weaving the coarse cotton cloths in which nearly the whole labouring population of Lombardy and the Venetian provinces are clothed, and also for the processes in the manufacture of silk, which is so abundantly produced in these provinces. I came in contact with many of these small proprietors, and

saw their cottages and style of life. The impression I received was favourable to their intelligence, and a certain independence of character and opinion was noticeable in their conversation. The population increases very slowly here; and dense though it is, almost beyond precedent, I cannot say I saw signs of its being too dense for the capabilities of the soil. The slow rate of increase, perhaps, indicates a close equilibrium between the numbers of the people and their means of subsistence; but I do not think the one has *yet* begun to press injuriously upon the other; for I saw no squalid poverty, but many indications of a considerable amount of material enjoyment.

In the low country, the influence of irrigation in increasing the population is very discernible, when the districts there are compared with each other. Thus Lodi has a population of 475 per square mile, while Cremona, which is naturally quite as fertile a district, has only 367.5. The difference between the two arises from the fact that nearly the whole of the province of Lodi comes under the influence of the Muzza Canal, while in Cremona irrigation is much more limited. The rich meadow-lands, which cover a third part of the entire area of Lodi, exist only to the extent of one-seventh of the area in Cremona. To the corresponding abundance and richness of the products, the number of inhabitants is proportioned.

The total number of districts in Lombardy is 127; and if these are divided into three classes of maximum, mean, and minimum density of population, we have the following results :—

Districts of maximum population, where the ratio exceeds 375 per square mile, ...	43
Districts of mean population, where the ratio is between 375 and 250 per square mile, ...	48
Districts of minimum population, where the ratio falls below 250 per square mile, . . .	36

We can trace, in an interesting way, the influence of irrigation, by following, for a moment, the distribution of the districts of maximum population. Two-thirds of these, or 28, are found in the great irrigated tract between the Ticino and the Adda. Between the Adda and Oglio, a region less richly supplied with water, there are 11. Farther to the eastward, between the Oglio and the Mincio, there are but 4; while on the extreme limit of irrigation, between the Mincio and the Po, there are none. Within a circle of 30 miles radius—Milan being the centre—there are found no less than 35 of these densely-peopled districts, including among them several of the hilly tracts formerly adverted to.

To give an idea of the general distribution of the population, I annex the following

STATEMENT of the POPULATION of the PROVINCES of LOMBARDY.

	No. of inhabitants.	Ratio per square mile.
1. Province of Milan,	522,397	707.5
2. " Lodi and Crema,	206,314	465.
3. " Pavia,	157,022	402.5
4. " Cremona,	188,565	367.5
5. " Como,	373,216	355.
6. " Mantua,	252,406	280.
7. " Brescia,	356,604	267.5
8. " Bergamo,	344,207	200.
9. " Sondrio,	90,903	72.5
10. " Verona,	288,284	237.5

Our survey of the prominent characteristics of Lombardy, as a great field of irrigation, is now completed. It has shown us how wondrously nature has framed the machinery which this end required: how she has linked together into one vast co-operative system, the mountains, the lakes, and the rivers, the powerful summer sun, the cloudless skies, and the arid atmosphere; and how she has filled the land with an active and industrious population. We have now to show how far man has seconded nature,

and to proceed to the history and description of those great works by which he has turned to account the advantages we have referred to—advantages so manifest, that, if we were content to look only on the surface of things, and to forget that material comfort is not the only essential to the peace and happiness of an intelligent people, we might, I think, pronounce Lombardy one of the most highly favoured regions on the face of the earth. That, in point of fact, it is notoriously far otherwise at present, arises from causes wholly foreign to my subject, and which—though it was impossible to avoid tracing their influence with the deepest and most painful interest—I cannot allow myself to dwell upon here.

SECTION II.

HISTORICAL SUMMARY OF THE PROGRESS OF IRRIGATION IN LOMBARDY.

To the few faint and indefinite notices of irrigation in Lombardy during the classic times, which Italian writers have preserved, I have already adverted, and have seen cause to regard the works then executed as of individual, or at most of civic, rather than of national importance. The repeated irruptions of the barbarian hordes of the north into the valley of the Po during the earlier centuries of the Christian era, the incessant state of war of which this region was the theatre, and the general misery to which the population was reduced, led naturally to the neglect of even those works which in happier times may have been constructed, and, judging from the descriptions of the physical condition of the country which have been

preserved, threatened to leave the rich plain of Lombardy in a state scarcely superior to that of the Tuscan Maremma or the Pontine marshes. The same cause which has effected the ruin of these latter tracts was in active operation throughout Lombardy during the dark ages: the numerous rivers were unregulated and uncontrolled; and some notices of the state of the country during the tenth century prove that the inevitable results had followed in the formation of vast marshes, and the abandonment by the population of extensive districts, which the pestilential exhalations from these swamps had rendered uninhabitable. " A great part of the province," Bruschetti remarks, " was at this time covered with forests. Tracts, now richly cultivated, were then stagnant marshes or arid wastes. The cultivation of rice or the mulberry was unknown, and the products of the soil were the common grains required for food, and flax for clothing." Some traces of better times, however, still remained. The existence of water-meadows is adverted to; and the ordinary measures of their produce in grass or hay, which are still in use, are traceable as far back as the beginning of the ninth century. The struggle against the superabundant waters, which threatened to submerge the plain, did not, however, begin for two centuries later, and the great works undertaken to this end are cotemporaneous with the dawn of civilisation in Europe. Before the year 1100, but at what precise date is unknown, the ancient works in the interior of Milan, originally constructed in the times of the Romans, were restored and extended. Connected with these was the channel, still called the Vecchiabbia, or Vettabbia, which, commencing in the city, flows centrally through the province, and joins the Lambro at Melegnano, after a course of about ten miles. Into this channel, as an escape line, were collected a por-

tion of the waters of the four small streams, the Lambro, the Sevese, the Nerone, and the Olona, by means of the Redefosso, or ditch of the ancient city. The destruction of Milan by the Emperor Frederick Barbarossa in 1162, and its subsequent reconstruction on a grander scale about 1176, led to a great extension of these hydraulic works. The dam of the Ponte d'Archetto was constructed, by which the entire volume of the Nerone was directed through the city, and conveyed by its sewers to the Vettabbia. These subterranean channels were greatly enlarged and extended; and further supplies were derived from the Lambro, Sevese, and Olona, securing for the newly-built city a thorough drainage, and an abundant command of water for all public and private wants.

Up to the middle of the twelfth century we find no reference to the employment of these waters for irrigation. Continued local traditions, however, establish the fact, that during the latter half of this century the modern system of irrigation had its origin. It was to the intelligence of an order of monks that Lombardy was indebted for this blessing. "The historian Landolfo relates," says Bruschetti, "that shortly after the departure of St Bernard from Milan, a party of his monks arrived there seeking charity; and by this means they collected so much money, and so many precious articles, as to enable them to found the noble monastery of Chiaravalle, near Milan, and to bring under cultivation a large extent of land in its immediate vicinity. Great works could at that time be executed only by such religious corporations, of which many, having effectively assisted the Lombard League in freeing the country from the hateful dominion of strangers, became possessed of large resources and power, which enabled them to effect improvements beyond the capacity of private par-

ties. The monks of Chiaravalle, accordingly, seeing that even during the latter half of the twelfth century the waters of the Vettabbia were neglected, gradually, and with facility, obtained possession of them, turning the whole of them to the irrigation of their meadows and fields. Having once obtained a right of property to the stream, they guarded it with the utmost jealousy, and vigorously maintained possession against every claim. To secure them against interference with their employment of the waters, they obtained ultimately the confirmation of their rights by the government." Such was the first dawn of that system which, commenced by the Cistercian monks of Chiaravalle, had its value early recognised by the community, and shortly afterwards led to the construction of the great canal of the Ticino, which —as a canal of irrigation—yields in magnitude only to the works constructed by the British Government in India.

All historians of the period under notice advert with natural pride to the vigour which characterised the purely Italian government of the Milanese in all internal improvements. The defeat of Barbarossa at Legnano by the League of the Lombard cities, and the definitive peace of Constance, secured a temporary repose from the horrors of war; and this was most actively employed in works of peace. The canal of the Ticino dates from 1177, a year after the battle of Legnano; the formation of the lakes of Mantua, —by the construction of the curious works on the Mincio, which to this day attract the notice of the traveller under the name of the Porta Mulina,—from 1188. In 1191, the Canal della Battaglia (named evidently in commemoration of the victory of Legnano) was constructed near Padua by Guiglielmo dell' Osa of Milan; and in the same year Bologna granted to an association of its citizens the right of forming a canal from the Reno. In illustra-

tion of the value thus early attached to water for irrigation, I may mention that in 1183 the inhabitants of Modena and Reggio actually went to war in defence of their respective rights to the waters of the Secchia, and kept up the quarrel with great folly and much mutual damage for twenty years, when it was adjusted by the good offices of the Podestas of Parma and Cremona, acting as arbitrators.

Not only did great activity in the execution of works prevail during the twelfth century, but to the same epoch is referable the distinct establishment of that *Diritto d'Aquedotto*, or Right of Passage for water from its source to the sphere of its employment, which is regarded as the "Magna Charta" of irrigation in Lombardy. It is first distinctly established in the ancient Statutes of Milan of this period, though there is every reason to believe it had existed as a custom from time immemorial.

The thirteenth century is memorable for the completion of the works of the Naviglio Grande, for their being made navigable up to the walls of Milan, and for the continued extension of the system of irrigation over the low country. In 1220 the Canal Muzza, the greatest of the lines derived from the Adda, was commenced. It is a curious fact that the construction of works of irrigation should so often have been selected by the republic of Milan to commemorate its great victories; for, as the canal of the Ticino was undertaken immediately after the defeat of Barbarossa, so the Muzza, or New Adda, as it was then called, was completed, and connected through the Addetta with the Lambro, during the year 1239, when the Emperor Frederick II. had been defeated at Cascino Scanasio. During the course of the century various improvements and extensions of the works were successfully effected.

During the fourteenth century the Naviglio Civico of Cremona, deriving its supply from the Oglio, was constructed; and other minor canals, of no great importance, are traceable to the same period. In 1359, reference is made by old authorities to the construction of a canal of Pavia, linking Milan with that city; but as locks were then unknown, the line must have been simply for irrigation.

In 1457 the Canal Martesana was commenced by the Duke Francesco Sforza I., and finished within a few years. Though not the first, it was one of the earliest works of this class to which locks for navigation were applied; and it is a cherished tradition that their constructor was Leonardo da Vinci, who became Engineer in Chief to Ludovico il Moro in 1498. The founders of Milan placed that capital in a position eminently unfavourable for benefiting by the natural advantages the rivers of Lombardy present; but by the junction under its walls of artificial lines connecting the Ticino, the Adda, and Po, all the facilities of water-carriage were secured to it, without any of those inconveniences, and even dangers, to which the immediate vicinity of large rivers—especially such as those of Northern Italy—frequently exposes the towns upon their banks.

The canal of Bereguardo is another work attributable to the fifteenth century, as it was commenced in 1460, and terminated about 1470. The Naviglio Interno of Milan, by which the interior communication of the city was effected, belongs to the same period, having been finally completed by its junction with the Canal Martesana in 1498.

By the sixteenth century the great lines of irrigation were completed, but the extension of the system in detail was vigorously prosecuted. It was then felt that the

administration and distribution of the waters were becoming of the highest importance; and it is at this period that we have the commencement of that system of distribution by Modules, which, though certainly not perfect, has yet been of the utmost use. The canal of Paderno, on the Adda, is the only original work of importance which dates from the sixteenth century, having been begun in 1518, though not finally completed until 1777. Among private undertakings of this time, the Naviglio Pallavicino—so called from the noble family by whom it was executed—is the most remarkable. However unpleasant in other respects the recollections of the dominion of Spain in the Milanese during the sixteenth and the succeeding century may be, it is certain that in all matters connected with irrigation the government was liberal and vigorous. The experience of the results of such works executed throughout Spain in abundance, and on a large scale, by the Mahommedan Caliphs, doubtless secured for them the attention and interest of the Spaniards in Italy.

From the seventeenth century to the present period, the canal of Pavia, executed in the time of the Kingdom of Italy, is the only great work completed by the State. Commenced in 1805 by order of Napoleon, it was only finally perfected in 1819.

This rapid sketch shows that the period between the twelfth and fifteenth centuries, remarkable as the most brilliant in Italian history, was by far the most fruitful in works of irrigation. Amid intestine troubles and foreign wars, the system was continually and vigorously developed; and, considering the incalculable benefits which, during the lapse of more than six hundred years, it has conferred on the country, some sympathy will be felt for the pride with which the Lombards have always

regarded, and continued to regard, their great chain of canals.

The separate links of this chain now require our attention.

SECTION III.

CANALS OF THE TICINO.

1. THE NAVIGLIO GRANDE, OR GRAND CANAL OF THE TICINO.

The early history of this work is involved in considerable obscurity; but in the subsequent sketch of it I follow Lombardini and Bruschetti, as being, I believe, the best authorities available.

The general impression is, that the Naviglio Grande was first constructed from Tornavento to Abbiategrasso in 1177 or 1179, and carried onward to Milan only in 1257. But Lombardini quotes proof to show that the existence of the canal, as a purely irrigating line, dates many years earlier than 1177. His opinion is, that a canal of irrigation, under the name of the Ticinello, or Little Ticino, was drawn from the river at Tornavento, and connected with the Lower Olona at an undetermined date prior to 1177; that in the course of that year this line was made navigable as far as Abbiategrasso, and prolonged —for irrigation only—to Milan by Gaggiano and Trezzano. The existence of this latter line is alluded to in a charter of the Abbey of Chiaravalle, under date 1233, which shows that Milan was connected with the Ticino, though in an imperfect way, before 1257, the date to which the

connection was formerly referred. In that year, however, Gozadini, Podesta of Milan, enlarged the canal, and perfected the navigation to the city. Further improvements, by which the passage of boats within the city was facilitated, were made in 1272 by order of Napoleone Torriano, the Guelphic chief of the State.

By whom the plan of the great canal was designed we do not know. No trace is left in any of the ancient records of even the names of the engineers employed upon it. The earliest reference to the work is in the ancient Statutes and Customs of Milan, first compiled into a written code in 1216; but from this no specific information, either as regards the original conception or the actual execution of a work which had then no model, can be gleaned. Like the designers and constructors of so many records of ancient civilisation in other lands, the engineers of the Naviglio Grande, to whose skill and energy great honour is due, have passed into utter oblivion. From records of a somewhat later period, it appears that the waters were not always used for peaceful purposes; as the historian Verri narrates that in 1329 the citizens of Milan suddenly turned the whole of the Naviglio Grande and the Ticinello into the intrenched camp of the Emperor Frederic II., between Besate and Casorate—thus forcing him to withdraw from it, and to expose himself to the defeat which he immediately afterwards received.

The year of the opening of the canal for navigation was remarkable for the greatest flood of the Ticino of which any record has been preserved. In 1177 the river rose 18 *braccia*, or 34.56 feet, above low-water mark, and whatever works had been constructed in the bed of the river were doubtless swept away. The injuries caused by such floods led early to the construction of escape-lines, by which the surplus waters were carried off from the bed of the canal,

and discharged into the natural drainage-lines of the country. The escapes of San Cristoforo and Benasco are nearly cotemporaneous with the canal itself. The former, situated a few miles from Milan, is the head of the Southern Lambro, and is connected with the old bed of the Olona river, which before this time had been diverted bodily from its former course, and carried in an artificial channel to the city. The bed, thus abandoned, having a rapid fall, and being connected with the Northern Lambro—and through it with the Po—was well calculated to receive and carry off the excess of water in times of flood. From the Benasco escape, which had its head near the town of that name, a cut was made to the natural channel, which bears the name of the Southern Olona, and joins the Po near Belgioso.

The history of the Naviglio Grande, for a century after its completion, is a continued record of discontents and disputes regarding the supply of water. The secret of this state of affairs was simply that no regulations whatever had been established for the distribution or measurement of the water, and the authorities contented themselves by merely prescribing certain heights and breadths for the outlets in an arbitrary and indefinite way. The law of the strongest was therefore in full force, and the quarrels between the consumers were often of a very serious character. Some attempt was made to rectify these disorders, by the nomination, about 1271, of a special commission, consisting of two clerical and two lay members, who were invested with administrative and police powers in all matters connected with the canal. The interests concerned were, however, too powerful to be controlled, especially as, during the superiority of the Visconti in Milan, it was part of the policy of that family to conciliate, in every possible way, the privileged classes,

whether noble or religious. Hence grants of water from the Naviglio were made in the most reckless manner to reward private services, or to purchase the support of such powerful corporations as the monasteries of Chiaravalle, or of the Certosa of Pavia. I find that another cause of bitter complaint during this period was the establishment of that system of farming the revenue to one or more individuals, which I have before described as still existing in Piedmont. It is characterised by the historian Verri as "a system of selling the peace, the security, and the liberty of the people, to a farmer interested in exercising every sort of annoyance to increase the profits of his speculation."

In 1376 the great Jean Galeazzo Visconti, the friend and protector of Petrarch, the founder of the Duomo of Milan, and the Certosa of Pavia, resolved to reduce to order the chaos into which the system of irrigation from the Naviglio Grande had fallen. On the 6th of February he issued an ordinance, declaring that the whole of the outlets must be regulated, and that the form prescribed in the Statutes should be rigidly observed. This form was in itself, however, extremely rude, being merely a rectangular outlet, the discharge from which was expressed in *rodigini d' acqua*, or the quantities of water required to drive a mill-wheel. The superficial area of outlet corresponding to each *rodigine* was 72 Milanese inches, or 4 in height and 18 in breadth—the only farther provision being that the sill of the outlet should be fixed 8 inches above the level of the bottom of the canal. It will be seen at once that, under such a system, neither certainty nor uniformity could be obtained; and though efforts were made to enforce the orders of Galeazzo, no permanent improvement was the consequence.

There was a constant tendency, on the part of the

supreme authority, to resume, from time to time, exclusive possession of the waters of the Naviglio Grande; but these efforts were invariably met by such resolute opposition on the part of the powerful body of citizens, of all grades and classes, to whom grants had been assigned, that even the despotism of the Visconti was foiled. Thus in 1446, under date the 19th of February, the Duke Filippo Maria Visconti published an ordinance, annulling at once, and without appeal, the whole of the rights to water from all the rivers, canals, and streams of the Milanese. The immediate consequence was a frightful tumult, for no instance was on record of such a sweeping annihilation of private rights; and the custom of the country had ever before been for enactments of this class to be made, nominally at least, with the consent of the Senate and Representatives of the people. So threatening did the aspect of affairs become that the Duke was obliged to modify the decree by limiting its operation to the rivers and canals, the admitted property of the state, while all others were left intact; but even upon the Ducal canals, including the Naviglio Grande, the terms of the decree were very imperfectly, if at all, enforced. In fact, the examination of the various edicts issued during the fifteenth century by the Visconti, and their successors the Sforzesci, proves clearly that, in a matter so nearly affecting the pecuniary interests of their subjects, great delicacy was forced upon Princes usually reckless enough; and in the combined action of the great lay and religious proprietors, whose incomes and influence were intimately dependent on the undisturbed possession of their means of irrigation, there was a constant and efficient check on the despotism of the Chief of the state.

In 1472 Francesco Sforza established the custom, which still remains in force, of effecting all repairs of the

canal during the month of March of each year, being just before the season of irrigation begins, and the time when the agriculture of the country suffers least from the want of the water.

Down to the commencement of the sixteenth century, we find the state of internal disorder we have alluded to prevailing with undiminished effect. In 1503, however, the Magistracy of Milan commenced in earnest to grapple with the difficulties of the case; and from this time forward the march of improvement was in advance, though still with occasional haltings and waverings. Four years previous to the date just mentioned, Louis XII. of France had obtained possession of the Milanese; and an early act of his government was the nomination of a new commission to regulate the distribution of water from the Naviglio Grande. Under date 1503, a magisterial decree was issued (the original of which still exists among the Archives in San Fidele at Milan), ordering that all the outlets should be reduced to the uniform height of 4 inches; that they should be cut in a single piece of stone, not more than 3 inches thick; that each outlet should be furnished with a chamber about 16 feet in length, with certain arrangements for regulating the velocity of the issuing stream, which need not be detailed here; and, finally, that the sill of the outlet should be fixed at 1.92 feet, or 1 *braccia* above the level of the bottom of the canal. In these provisions we have the first imperfect germ of that *modulo magistrale* which, at the present time, is the established measuring apparatus of the Milanese. Under Francis I., and, after his famous defeat at Pavia, under the dominion of the Spanish house, the decrees concerning the canals are most numerous. Scarcely a year is found to pass without some record of action on the part of the government. I do not find in these numerous

documents, the substance of which is given by Bruschetti, in his "*History of Irrigation,*" much that is of interest. They show that the various elements of a sound and satisfactory system of distribution were being slowly established; that the hydraulic principles on which such a system must be based were being recognised in succession; that, so to speak, the stones were being collected, shaped, and polished, one by one, awaiting only the intellect and the courage of the architect to combine them into one enduring edifice. When the time was thus ripe for a permanent reformation, the man was also found who, in moral and intellectual qualities, was fitted to carry it into effect; and I think a rapid outline of the history of Giacomo Soldati, the inventor of the *Modulo Magistrale*, will be both interesting and instructive to every one who is personally concerned in questions connected with irrigation, and especially to those who, like myself, may have to administer a system the existing condition of which has a strong resemblance to that reduced, in some degree, to order by the efforts of Soldati.

In pursuance of their determination to regulate the outlets of the Naviglio Grande, the Magistracy of Milan, during the year 1570, called upon various engineers for their opinions on the best method of effecting this object. Among those who obeyed their summons was an architect and engineer of Milan, by name Giacomo Soldati, then occupied in the private practice of his profession. He stated in his first communication, that, until means were devised for maintaining a constant head of pressure—or, in local phrase, a "*battente stabile*"—on each outlet, all other means of insuring regularity of discharge must be vain. Every variation of level in the main canal would necessarily derange the discharge of the outlets; and to the object of neutralising the effect of such variations, he

held that attention must first be directed. He declared himself prepared to submit to the Magistrates a machine of his invention, by which the desired object would be effected. In January 1571, Soldati was received by the Commission of Irrigation, and described to the members the plan of his *modulo* in detail. As this will be minutely described hereafter, I need only say now, that the plan received the cordial approval of this body. It was a fortunate circumstance that its president, Signor Danese Filiodone, was a man of resolute courage and clear intellect, who entered into Soldati's views with zeal and cordiality, and determined to support him against all opposition. To provide against all foreseen contingencies, the magistracy prescribed twelve separate conditions to Soldati, on each of which he was required to give his opinion. These conditions were briefly—1st, To establish a just and exact unity of measure; 2d, To devise a form of apparatus for the outlets, which should be injurious neither to the State, nor to the consumers of the water, nor to the navigation of the canal; 3d, To protect the apparatus from all risk of alteration in its essential parts by the cultivators; 4th, That precautions should be taken against infiltration from the main canal into the private channels; 5th, To regulate the velocity of the stream passing through the outlet, so as to render it as far as possible independent of the velocity of the main canal; 6th, To insure the same discharge from the new form of outlet in summer and in winter; 7th, To establish, in the event of a deficiency of supply in the main canal, a fair method of decreasing proportionally the discharges of the different outlets; 8th, To provide for the possible contingency of a permanent increase in the supply of the main canal, so as to prevent in such case the consumers from getting more than their fair share of the

water; 9th, To make the discharge of the outlets independent of variations in the level of the bottom or bed of the main canal; 10th, To establish, by some unalterable mark, the true level of the bed of the main canal at each outlet, so that it might be at all times recognisable with facility, and verified whenever necessary; 11th, To devise such a system of management of the outlets as to place in the hands of the government officers the power of either closing them altogether, or diminishing their discharge with facility in all periods of extreme dryness; 12th, To point out in detail the best means of reconciling the often conflicting interests of navigation and irrigation, so that, in periods of extreme dryness, the quantity of water essential for the former might be maintained with the least possible inconvenience to the latter.

Such were the conditions of the problem Soldati was required to solve. It will be clear, that to satisfy them all perfectly would be impracticable, even with the increased knowledge of the present day; and in his reply to the magistracy, under date the 14th February 1571, Soldati frankly and fairly states, that he cannot undertake to remove all the difficulties suggested, but that he is prepared to obviate some of the principal, and to effect important improvements on the existing arrangements. Just a month later, on the 15th of March, he submits ample details of his views as to the improvement of the canal, and the regulation of the outlets. Discussions on these plans were continued for nearly a year, but the final result was, that the Magistrates approved of the whole, and in the spring of 1572, Soldati was vested with full powers to carry forward his proposed reformation. In August of the same year he submitted his first report of progress in his work, and states that the outlets were being gradually remodelled one by one, at the expense of

their owners, though not without great opposition and personal annoyance. It was now that the moral qualities of the man were displayed. A great combination of the proprietors, whose illegitimate encroachments on the canal were threatened, was formed against him; every engine of vexation was employed to harass him; his employers in his profession as an engineer deserted him, his private fortune was ruined, his life itself was threatened, and the traditional fate of the Podesta Beno Gozadini—who, having roused the passions of the people by acts of reform similar to his own, was cruelly murdered, and his body thrown contemptuously into the canal he had improved—was not obscurely pointed out as a warning to himself. But firmly and fearlessly Soldati persisted in following his own course, and confronted his adversaries in whatever form they presented themselves. In September 1572, a determined attack was made on his system by Bernardino Lonati, an eminent engineer in the service of the government, who had himself been previously employed in attempts to remodel the distribution of the water, but who was now in the interest of the malcontents. Lonati asserted that the outlets of Soldati supplied *twice* the quantity of water which was due; but the latter executed a measurement in presence of the Magistrates, and showed, to their perfect satisfaction, that the discharges of his outlets corresponded as closely as was practicable with the quantities fixed in the original grants, while the old outlets gave in all cases much more. As was natural, however, no proof of this kind was satisfactory to the proprietors. The opposition continued as determined as ever, and in 1573, Soldati wrote to the Magistrates in depression and sorrow, that he was almost unable to withstand it. He was fortunate, however, in finding this influential body invariably his firmest friends

and supporters. In a letter under date the 17th April 1573, they encourage him to perseverance, assure him of their unimpaired confidence, and offer him whatever additional aid he requires. Thus cheered, he renewed his efforts to bring his difficult task to a close, and his labours were lightened and his responsibilities divided by the appointment of Giovanni Battesta Lonati as his coadjutor. By the 28th of May 1573, Soldati and Lonati were able to report that their reforms had placed at the disposal of the State a quantity of water equal in winter to 100 oncie, or about 150 cubic feet per second, and in summer to 500 oncie, or about 750 cubic feet.

Soldati's troubles were, however, by no means ended, and as his work approached its close his assailants became more and more determined. In October 1573, he demanded the appointment of an extraordinary Commission, to witness another comparative experiment with his form of outlet and that in ordinary use. Ten of the most eminent lawyers and engineers of Milan formed the commission, and watched the results of the experiment. It is curious and interesting to find among these men the famous architect of the Escurial of Madrid and the Duomo of Milan, Pellegrino de Pellegrini, and it is pleasant to have to tell that he gave to Soldati his firm and friendly support, reporting personally to the Magistracy that he considered his apparatus to be admirable, and calculated at the least possible expense to correct the disorders of the Naviglio. The opinion of the Commission collectively was to the same effect; but the Government, not being fully satisfied, deputed Sitoni, one of the most virulent of Soldati's opponents, to visit the canal, and to report his opinion on the measures adopted by the latter. The result was, of course, a violent attack on Soldati, which seems to have roused him

to the utmost indignation. It was a time of chivalry in science as well as in arms, and, in accordance with the custom of the period, he challenged his assailant to single combat—not, however, with sword or spear, but with such weapons as both were supposed to be able to handle better — " the eight sciences which constitute a good architect." * This curious challenge defies Sitoni " to prove in writing within thirty days all the evil he had spoken, especially with reference to the remodelling of the outlets, under pain of being branded before the public by such epithets as best become those who, in self-conceit, malignity, or ignorance, damage the fair fame of others;" and then follows the challenge to the public contest above referred to—a species of intellectual gladiatorship, which, common enough among the schoolmen of the Middle Ages, only now appears at rare intervals among ourselves, in the public discussions of excited theologians. What the exact result of Soldati's combat was does not appear, but he probably issued victorious from it as from the other trials to which he was subjected. Sitoni's attack upon the system, however, had a powerful effect in encouraging opposition; and as the process of reform approached Milan, and touched upon the rights of the great lay and religious proprietors concentrated round the capital, resistance to the magistracy became open and violent; renewed menaces were directed against the reformer; while death had been busy among the staunch friends who had hitherto supported him. About the same time, too, all men's minds were distracted from less serious matters by that terrible plague which in 1576 nearly depopulated Milan, and for a time disorganised its government and society. To this scourge the president, Filiodone, and many

* These are Writing, Drawing, Arithmetic, Geometry, Optics, Physics, Mechanics, and Hydraulics.

of the other magistrates, fell victims, so that Soldati now lost the support they had always given him in the council-chamber. These various causes co-operating led to the suspension of the work of reform, which to this hour remains imperfect, the usurpations of the great proprietors having, in fact, now become rights by prescription.

The last view we have of Soldati is touching in the extreme. Reduced to utter poverty, deserted by his clients, persecuted by his opponents, we find him in 1578 appealing for the means of subsistence to the Magistracy, representing that, as the small salary granted to him while his work was in progress had now ceased, he was in danger of starvation. The appeal was favourably received, and a moderate pension of nine lire *per diem* was settled upon him for life. Such is the history of the invention and introduction of that "*Modulo Magistrale*," which is admitted at the present day to be the best means of issuing water for irrigation which we possess, and of the *Oncia Magistrale*, which continues to be the established unity of measure in the Milanese. The narrative given is not only interesting as a record of indefatigable perseverance amid great and ultimately overwhelming difficulties, but it is most instructive. It shows clearly the danger of allowing a great system of irrigation to develop itself without well-defined regulations — of permitting interests to grow up either in ignorance or neglect, which, infringing the rights of the government, oppose themselves afterwards with obstinacy and vigour to improvement of any kind: and it is because I believe our system of irrigation in India to be exposed in its present stage to dangers of this very order that I have been led to dwell so long on this part of the history of the Lombardian canals.

With us the value of water is becoming daily greater

as the demand for it increases. We are no strangers to the violent disputes which even now occasionally arise. Yet our grants are made in the most indefinite terms. We have no unity of measure—no regulating apparatus superior, or indeed equal, to that employed by the Lombards nearly three hundred and fifty years ago. We are going on in a hap-hazard way, laying up for ourselves sources of trouble and annoyance, which, though they may not lead to such extreme results as we have seen prevailing under analogous circumstances in Northern Italy, will inevitably cause much discontent and irritation when the necessity for exterminating them shall arise. I am anxious, therefore, not to lose the opportunity of urging the introduction into our Indian system of well-considered rules for the measurement and distribution of the water, and of profiting by that experience in other countries of which the foregoing narrative is an illustration. The spirit of my remarks on our system in India will, I trust, not be misunderstood. When it is borne in mind that its development, at first very slow, commenced only thirty years ago—that we have in this short space of time brought under irrigation an area considerably in excess of the entire irrigated surface of Lombardy—and brought nearly to completion works which will ultimately quadruple the present extent of irrigation, it will cause no surprise, and will assuredly escape all blame, that our legislation should still be found imperfect. The past has been devoted almost exclusively to the construction and extension of our works; but the time has, I think, arrived when less material objects, neglected hitherto from necessity, require attention on the part of the government, and the officers of the department, and it is to support this view that I have adverted to the imperfections existing in our administrative system.

The history of the Naviglio Grande presents no prominent points for notice until 1705, when a flood of the Ticino, only surpassed in violence by that of 1178, carried away the whole of the head-works, changed the course of the river, and threatened to render useless the entire line of the canal. The Magistracy of the time set themselves to repair the disasters with their usual vigour, and a commission of four engineers, with Count Carlo Borromeo and Marquis Carlo Francesco Visconti, as representatives of the city of Milan, having estimated the cost of repairs at 300,000 lire, equal to nearly £40,000 of our money at the present day, exceptional measures were adopted for raising the funds. The resources of the State not being sufficient, the parties benefiting by the other canals of irrigation were required to contribute; the ordinary charge for navigation was increased by three-fourths of its previous amount, and each outlet of irrigation was subjected to a tax of 100 lire on each oncia of permanent, and 80 on each oncia of temporary discharge. Means were thus found for the employment of more than 4000 workmen daily; the Magistrates deputed one of their own body to visit the works in rotation, to encourage the engineers and labourers; and as a consequence of these vigorous exertions, the repairs, commenced in January, were finished by the end of March, and the water admitted into the canal. This was the second time these great works had been renewed, their first destruction having been caused in 1636 by the French army, which, much to its own disgrace, destroyed the inlet at the head, the banks and escapes, so that the country was for a time deprived entirely of irrigation.

In 1751, the Ticino having become the frontier line between the Kingdom of Sardinia and the Lombardo-Venetian provinces, the supply of water from it for the Naviglio Grande was secured by treaty, and a priority of

right to such quantity as might be necessary for this canal was established. In times of scarcity, therefore, the Naviglio Grande is the first line from the Ticino to be provided with water; and the Milanese has thus a considerable advantage over the territory on the right bank, supplied by the canals Langosco and Sforzesca.

From the middle of the eighteenth century to the present time, no works of material importance have been executed on the Naviglio Grande. Various floods—as in 1755, 1787, 1789, 1792, and during the current century, in 1810, 1823, 1829, 1834, 1842—have caused considerable injuries to the works; but I do not find any points connected with these of special interest, and I may now, therefore, pass on and give a short descriptive account of the canal itself, and the principal works upon it.

The Naviglio Grande, in its general appearance, bears a striking resemblance to those canals which were constructed by the Mahommedan emperors of India. Originally excavated at a time when engineers were ignorant of the use of masonry falls, the excessive slope of the country through which the canals—whether of Lombardy or Northern India—were carried, was overcome by the same expedient of forming the channel in tortuous lines, and thus giving them the additional length which the adjustment of the slopes required. Hence both classes of works have the aspect of rivers rather than of artificial canals.

The Naviglio Grande, from its head at Tornavento, on the left bank of the Ticino, to its termination at the new dock under the walls of Milan, has a length of 31 miles. From its head to Buffalora, a distance of 13 miles, it skirts the valley of the Ticino in an exceedingly tortuous channel; and at the latter point it enters the plain, passing by Robecco and Casteletto to Milan, and crossing

the districts of Gaggiano, Trezzano, Corsico, and St Christopher. The channel is in deep excavation from Buffalora to Robecco ; this depth decreases from the latter point to Casteletto, where the bed of the canal is but little, if at all, below the natural surface of the ground ; and onward to Milan, the channel is sometimes in excavation, sometimes in embankments, according to the varieties of slope it meets with. The total length is thus distributed :—

	Miles.
In the Province of Milan, . . .	9½
Do. of Pavia, . . .	14½
Do. of Milan, . . .	7
Total, .	31

The first portion of the channel exhibits extreme irregularities both of breadths and depths. The former vary from 75 to 160 feet, the latter from 4½ to 15 feet. The slopes are not less capriciously distributed, ranging from 3.75 to as much as 7.75 feet per mile. These data exhibit very clearly the imperfect knowledge of the times when the canal was first made. The second portion, which traverses the province of Pavia, is not quite so irregular as the preceding, though still remarkable enough in this way. The breadths vary from 60 to 80 feet, the depths from 3.25 to 8.75, and the slopes from 1 to 5.7 feet per mile. On the last portion, which terminates at Milan, the breadths vary from 40 to 60, the depths from 3.84 to 8.16 feet. The mean slope is 2.84 feet per mile, very nearly double what it ought to be in a well-constructed canal destined both for irrigation and navigation. The following more detailed series of levels along the line has some interest :—

	Distance in miles.	Total fall in feet.	Fall per mile in feet.
Sill of Dam at head,	0.00	0.00	0.00
Bridge of Castano,	3.34	27.20	8.02
„ of Turbigo,	1.10	4.99	4.53
„ of Paregnano,	1.16	7.52	6.48
„ of Casteletto,	2.78	10.48	3.08
„ of Bernate,	1.86	2.01	1.08
„ of Buffalora,	0.98	1.44	1.47
„ of Magenta,	1.75	8.80	5.02
„ of Robecco,	1.54	9.12	5.09
„ of Cascinetta,	1.42	8.80	6.02
„ of Castelletto-Abbiategrasso,	...	...	...
Head of Canal of Bereguardo,	2.16	13.42	6.02
Bridge of Gaggiano,	4.76	9.37	1.09
„ of Bonirola,	0.78	0.64	0.88
„ of Trezzano,	0.98	0.76	0.07
„ of Corsico,	2.16	2.11	0.09
„ of S. Christofero,	2.50	1.34	0.05
„ of Road round the City,	1.10	0.03	0.00
Fall of Viarenna Lake and Dock of the Porta Ticinese,	0.65	0.00	0.00
Totals,	31.02	108.03	3.05

These figures show how very imperfectly the bed of the canal has been constructed, and how irregularly its inclination is distributed. The tenacity of the soil alone has prevented serious difficulties arising from these faults of construction, which, even with this advantage, have entailed heavy expenses in protecting the banks and paving the bottom of the channel.

The most important work on the canal is the great dam, which is carried obliquely across nearly the entire bed of the Ticino, leaving on the right bank only an opening of about 215 feet in width, which is termed the "Bocca di Pavia," or Mouth of Pavia. The dam itself is named the Paladella, and has a total length of 918.47 feet; its breadth varies from 31.10 to 58.33 feet, with the exception of a length of 120 feet at its outer extremity, which has a breadth only of 7.84 feet. The body of the dam is formed partly of masonry, concrete,

and masses of dry stone, bound by strong piles and horizontal beams of wood. The mixed mass of brick masonry and concrete, of which the principal part of the work is composed, is covered by a pavement of cut stone very strongly fitted and bound together. The exterior slope is similarly revetted; and both towards the river and within the bed of the canal, massive walls protect the banks from the action of the stream. On the Lombard side, the great dam is terminated by a brick masonry wall having a slope paved with flag-stones or boulders; and on the Piedmontese side, the extremity which abuts on the Bocca di Pavia is protected by masses of loose stones, which extend not only along this portion of the dam, but down the banks of the river also. The Lombard end of the dam was carried away for a length of 120 feet in 1819, and a few years ago another accident damaged about 140 feet. It is a strong proof of the stability of the work, that these should have been the only two serious accidents which have befallen it since its reconstruction after the great flood of 1705. With its favourable alignment, its admirable foundation in the strong compact gravelly bed of the river, its solid construction, and the abundant means of escape for the surplus waters, the dam of the Paladella is one of the strongest works of its class in Northern Italy.

The means of discharge in great floods are supplied, 1st, by six grand Weirs, the bodies of excellent masonry, the exterior slopes of masses of stone, sometimes with, at other times without, cement, paved on the upper surface, and provided with frameworks of wood on the sills to facilitate the construction of temporary dams of fascines, to retain, when necessary, the waters within the canal bed. The flanks are protected either by walls of masonry or by piles, and the whole of the works are carefully and solidly

built. 2d, By twelve escapes, having a total number of 185 sluices, each from 2½ to 2¾ feet in breadth, and managed by means similar to those in use on the canals of Piedmont, namely, an upright iron racket fixed to each sluice-gate, and a simple lever, which one man ordinarily applies to raise or close the gate. There is nothing worthy of special note in the construction of these escapes: they consist each of a solid mass of masonry in the foundations and body, with arched openings below, fitted with gates. The combined action of the weirs, and the regulating escapes, gives a perfect command over the supply under nearly all circumstances. The escape-channels are under charge of the government officers, but the waters passing through them are employed both for irrigation and machinery. Where the fall is excessive, impediments to the free escape of the waters may be of little consequence; but in India, we have decided objections to the employment of escapes as irrigating lines, considering their efficiency for their special purpose to be much impaired by such use.

There are fourteen bridges on the canal, a provision for cross-communication much inferior to what we found in Piedmont. The great antiquity of the canal has rendered unnecessary those numerous siphons and aqueducts with which modern lines are studded for the passage of water the property of private parties. There are consequently only three works of this class on the Naviglio Grande. Seven dwelling-houses or store-rooms have been provided for the establishment, and for the protection of materials and tools of various kinds. The hydrometers are an important though very simple class of works. The method of issuing the water in force requires that the level of the surface of the canal should be maintained as nearly as possible constant; and to assist the guardians in this part of their duty, eight hydrometers have been erected along

the line of the canal, with the heights of water necessary for a full supply at its special locality marked upon each. The old ones are formed of a plate of iron fixed in an upright of stone, and graduated in Milanese measures; the new ones have the scale on a piece of white marble imbedded in a pillar of granite. The scales are in daily use, and the guardians are compelled to regulate the irrigation outlets according to the height of the canal water upon them.

The excessive slope to which I have already adverted has led to many parts of the canal bottom being paved with flat stones, or with boulders, and there are nearly 40 miles of revetment on both banks to protect these from being cut into by the force of the current.

The permanent establishment of the canal consists of six Guardians, to whom are intrusted the protection of the irrigation outlets against any fraudulent change of dimensions by the proprietors, the regulation of the supply of the canal, the charge of the works, and the police duties connected with the navigation. The guardian at the head is charged with the maintenance of the canal supply at its prescribed height, according to the indications of the hydrometers which are reported to him; and it is his duty also to take care that no boats enter the canal at Tornavento except such as are of the prescribed dimensions—viz., 2.4 feet draught of water, 15½ feet in breadth, and 5 feet in depth, with variable lengths. As his duties are the most onerous of the whole, he has only 2 miles in length of the canal to superintend, while the other guardians have 4 or 5 miles each.

The ordinary repairs are executed under contract, extending over 9 years. They amount to about £1700 per annum, or nearly £55 per mile. With water so free from earthy matter as that supplied by the Ticino,

the annual clearances of the bed of the canal ought not to be of serious importance. But it so happens—most probably, I think, from the excessive slope of the bed near the head—that the lower part of the canal is subject to constant filling up by sand; large quantities of aquatic plants, too, establishing themselves within the channel, give as much trouble here as in a tropical country. The admixture of the turbid waters of the Olona leads farther to considerable deposits. The result is, that the canal must be closed twice a-year, for the purpose of clearance: in spring for nearly a month, when a thorough repair is made; and in autumn for eight days, when the plants are cleared away, and minor repairs are executed.

There being no regulating bridges across the canal channel, the periodical closing is effected by means of a temporary dam of fascines, piles, &c., which is usually established at Nonate, where the breadth is limited. At distant intervals the dam is made at the head of the canal, and its construction is then an expensive and troublesome work. When I visited the canal in March 1851, the annual clearance was in progress, and it was consequently impracticable to descend to Milan by it, as I had intended doing. At intervals there are masonry bars carried across the channel, to fix the depths to which the clearance should be carried, so as to avoid needless excavation. This is a useful and simple precaution, which is worthy of adoption under similar circumstances elsewhere.

The discharge of the Naviglio Grande, according to the latest measurement to which I have had access, is 1851 cubic feet per second. Of this quantity 156 cubic feet per second constitute the supply of the canal of Bereguardo, and 213 cubic feet that of the canal of Pavia, leaving 1512 cubic feet disposable for the main

line, and supplying 120 irrigation outlets of various dimensions, of which 116 are on the right and only 4 on the left bank. Some materials exist for enabling us to approximate to the loss of water caused by filtration, evaporation, and waste in general on this line. Two very careful measurements have recently been made by adding together the separate discharges of each outlet from the main canal: according to the first measurement the total amount of these was 1612.5 cubic feet, and according to the second, 1773 cubic feet, the mean being 1692.75 cubic feet per second. Now, as the total discharge is 1851 cubic feet, the loss on the whole length of the canal is 158.25 cubic feet, or very nearly 5 cubic feet per second for each mile, a datum which may be useful in an approximate way, for it cannot be considered anything better.

The period of low water in the rivers of Northern Italy is, as in those of Northern India, the winter months, or from about the end of September to March. It occasionally happens, however, that this period is prolonged to April, and even May, when very great inconvenience to agricultural operations is the consequence. In such cases a temporary dam is constructed along the crest of the permanent dam; and in extreme cases, of which, however, there are but two on record, the whole of the water passing the Bocca di Pavia is turned into the canal, so that below the Paladella the Ticino is left quite dry. Inconveniences of this order, however, are rare in the case of the Naviglio Grande, and the irrigation dependent upon it is more secure than on any other canal.

The ancient history of the canal presents us with the results of several measurements of the discharges of the various outlets made at different epochs. In 1694 the united volume of the whole was found by the engineer

Pessina to be 1191 cubic feet; in 1785 it had risen to 1266; and at present, as before noted, it is 1512, exclusive of the supplies of the canals of Bereguardo and Pavia. It has now arrived at its maximum, for during summer the whole of the water which can be brought into the canal is absorbed, and the area of irrigation under its influence may be considered as the full measure of its capabilities.

This area, I find from the latest authorities, amounts to 93,440 acres in summer, and to 1750 in winter, the latter being exclusively *marcite* cultivation. The former number gives an area of summer irrigation equal to 61.8 acres for each cubic foot of discharge per second, a result above the general average, and indicating a careful economy of the water. The superficies above noted does not include the irrigation from the canals of Bereguardo and Pavia, for though these are in point of fact nothing more than branches of the Naviglio Grande, they are so large as to merit separate notice. The 116 outlets on the right bank of the Naviglio give rise each to a small canal which corresponds to a first-class distribution channel on the large canals of India. The dimensions of the minor canals referred to differ extremely, the Ticinello having a volume of 54 cubic feet per second; the Bocca-Bernate, of 46.5; the Bocca-Visconti, of 36; while others, as the Bochetti Calvi and Corona, have no more than 1½ cubic feet each; of the outlets there are 22, which are bound to return the whole of their surplus waters into the canal. The proprietors of the remainder have the right of disposing of the water in any way they please, and in many cases the sale of the surplus produces a considerable revenue to them.

The price of water on the Naviglio Grande has varied exceedingly; but it conveys very little real information to quote the sums paid for it in ancient times, since,

though these, as expressed in modern terms, appear small, they are not really so, when reference is had to the higher value of money in these days. For example, a decree of the government, about 1376, fixed the annual rent of water at one lira for each oncia. Another decree, under date 20th September 1551, fixed the annual rent of the same quantity at 6 scudi, or 36 lire. Twenty years later the rent is about 125 lire, and the increase is found to go on in a rapid progression, for, in the beginning of the eighteenth century, the rent for one oncia during summer had risen to 300 lire from Tornavento to Buffalora—to 400 from the latter point to the bridge of Venezia—and in the vicinity of Milan to 450; and at the close of that century the price was higher than at this moment, ranging from 500 lire at the head, to 700, or even 800, at Milan. These few data, extracted from old records, are not intended to give any absolute, but only some relative, information, and to illustrate the progressive increase of the value of water, without pretending to determine what that value really was.

The various charges for water at the present time are shown below, reduced to English measures and money rates:—

Purchase in absolute property of 1 cubic foot per second,	£291	10	0
Annual rent in perpetuity of 1 cubic foot per second of continued discharge (i. e. summer and winter), .	13	5	0
Annual rent in perpetuity of 1 cubic foot for summer irrigation, ...	12	10	0
Annual rent of 1 cubic foot for summer irrigation, taken from year to year, ...	7	3	6
Annual rent of 1 cubic foot, for winter irrigation, from year to year, ...	1	5	0
Annual rent of 1 cubic foot for winter irrigation, from year to year, within a radius of 5¼ miles around Milan, .	1	12	0

We have already seen that on the Naviglio Grande each cubic foot per second irrigates 61.8, or, for facility

of reduction, say 62 acres. The above rates, distributed by acreage, give, therefore, the following results :—

Cost of irrigation per acre, with water purchased or rented in perpetuity, ...	£0	4	3
Cost of irrigation per acre, with water rented temporarily,	0	4	0
Cost of irrigation per acre for marcite or winter-meadows, at the rate of 1.66 acres per cubic foot, . .	0	17	0

The rates thus shown for summer irrigation of permanent or temporary meadows, rice lands, &c., are extremely moderate and favourable to the cultivators. The marcite or winter-meadows are an exceptional kind of cultivation ; but as they give ordinarily three crops during the winter, and, in the vicinity of Milan, a cutting every forty or forty-five days, they can bear easily the higher price of water shown for them.

From the intimations I have already given of the manner in which, during the course of six or seven centuries, the waters of the Naviglio have been disposed of at the will of the various chiefs of the State, it will cause no surprise to learn that the actual income from the canal is extremely trifling, and in fact just covers the expenses. From all sources, including navigation as well as irrigation, the government revenue amounts annually to no more than £1796, 15s. It is the great landed proprietors of the Milanese, and not the government, who have specially benefited by the existence of the canal, as the addition to the annual rental of the district through which it is carried may be estimated very moderately at not less than £60,000 per annum.

The water of the Naviglio Grande, I may mention before concluding, is used extensively as a motive power, driving 160 wheels for corn-mills, and about 20 more for other objects.

II. CANAL OF BEREGUARDO.

So far as the ancient records guide us, it would seem that this canal owed its first origin to a freak of royal fancy, as its construction was ordered in 1457 by Francesco Sforza I., Duke of Milan, for the convenience of transporting himself and his court in boats to the vicinity of Pavia, where he had built and adorned several palaces, and had large private domains. In the course of that year the works were commenced under the direction of the engineer Bertola of Novate, and in 1462 the line was opened for navigation and irrigation. In 1470 great improvements were effected upon it, and it has continued from that time to the present day to be very valuable for the latter object, though the construction of the canal of Pavia has destroyed its utility as a navigable line.

The head of the canal is established on the right bank of the Naviglio Grande, a little below the bridge of Castelletto-Abbiategrasso. Its outlet from the canal is a simple weir, and the line traverses the districts of Bugo, Caselle, Morimondo, Coronate, Basiano, Besate, Motta, Visconti, and Zelada, terminating at Bereguardo. The distribution of level throughout its length is shown in the following Table; and as its inclination is rapid, the excess of slope is disposed of by eleven locks, the construction of which presents nothing new or remarkable :—

TABLE

	Distance in miles.	Total fall in feet.	Fall in feet per mile.	Fall at each lock.
Bridge of Abbiategrasso,	0.0	0.0	0.0	0.0
1. Lock of the Dazio, . .	0.92	0.96	1.04	6.1
2. Do. Bardani, . .	0.68	0.51	0.7	3.8
3. Do. Bugo, . .	0.68	0.02	0.0	6.56
4. Do. Morimondo, .	0.98	0.96	0.9	6.1
5. Do. Coronate, . .	1.04	1.18	1.1	6.8
6. Do. Basiano, . .	0.98	1.24	1.2	7.5
7. Do. Fallavecchia, .	0.86	0.32	0.3	3.2
8. Do. Riviera, . .	0.55	1.44	2.6	6.3
9. Do. Inferno (double),	1.42	1.12	0.8	7.8
10. Do. Motta, . .	1.16	1.89	1.6	6.8
11. Do. Zelada, . .	1.04	0.80	0.7	5.12
Piazza of Bereguardo, terminus of the canal, . . .	1.04	2.14	2.0	
	11.35	12.58 76.08	12.94	76.08
		88.66	1.14	

The fall of the bed of the canal of Bereguardo is very well regulated, and, except in the immediate vicinity of the locks, no paving or other protection for the bottom has been found necessary. The sides, however, are covered by revetment-walls for a length of about 5 miles. These walls are sometimes of brick or boulder masonry, and sometimes merely of dry-stone work. The embankments throughout are low, and of course vary in dimensions according to the levels of the ground. The mean breadth of the canal is about 35 feet. At a very few points this is increased to from 40 to 45 feet. The height of water at the head, which varies with that of the Naviglio Grande and the Ticino, ranges from 5.76 feet in summer to 3.84 in winter.

The works on this canal are few in number, and of no special interest in construction. In addition to the eleven locks there are but three bridges and five small sluice-escapes, intended for the free passage of springs during

the period of annual clearance. Regulating works are unnecessary, for the supply of water is limited ; and so long as the Naviglio Grande is maintained in its average condition, there is no risk of its subordinate channels receiving damage from excess of water. The interior dimensions are defined by fixed profiles in stone or wood, which prevent any excessive excavation during clearances. The level of the water is marked by a hydrometer at the head of the canal, made in the same way as those of the Naviglio Grande. The influence of the growth of aquatic plants is shown by the necessity for raising the supply of water, towards the end of summer, 3 or 4 inches above its ordinary height on the scale.

The supervision of the canal is intrusted to two guardians, the one having a district about 5, and the other one about 6 miles in length. With the exception of about half a mile, which is maintained at the expense of private parties, the canal is kept in order by the government, and the annual expenditure for its repairs is included in the sum of £1700 formerly given for the Naviglio Grande. The income is, in like manner, included in the returns for the same canal.

The quantity of water employed for irrigation amounts to 156 cubic feet, and it is distributed from 18 outlets. Of these outlets, 12 are provided with measuring apparatus, and they absorb 76.35 cubic feet. The remaining 79.65 cubic feet supply six outlets, which are unregulated or free, and are all situated on the right bank, near the end of the canal. The 12 regulated outlets are distributed in equal numbers on both banks in the upper part of the canal, and their discharges range from 16 to 1½ cubic feet per second. They are for summer irrigation only, and of the whole number there are but

three which have rights to water in perpetuity, the remaining nine having temporary rights renewed from year to year. All the unregulated outlets claim the right to a perpetual supply, based on a grant dating from 1553. Of the whole supply of the canal, no less than 123 cubic feet per second are alienated for ever from the government by gratuitous grants from the sovereign or otherwise, leaving only 33 cubic feet, from which a trifling annual revenue is derived.

The Canal Bereguardo is a marked example of the great difficulty of reconciling the necessities of navigation and irrigation in the same work. During summer the demand for water for agricultural purposes is so great that the strictest measures are necessary to secure even the small supply then required for navigation. When boats are passing, the whole of the outlets are successively closed between each pair of locks, and with the supply thus thrown into the channel the passage is effected, though still with great inconvenience.

In summer the whole supply is absorbed in irrigating 10,400 acres, being 66.6 acres for each cubic foot per second. The winter volume, amounting to 138 cubic feet, is only partially employed. The extent of marcite or winter-meadow is estimated at about 193 acres, and this requires for its constant irrigation 126 cubic feet per second, giving only 1½ acres for each cubic foot. The surplus supply is ordinarily, though not always, employed in temporary irrigation. The area of irrigation above noted is all within the province of Pavia, and embraces permanent and temporary meadows, cereals, and a considerable extent of rice cultivation.

III. CANAL OF PAVIA.

According to Lombardini, the first construction of a canal connecting Milan and Pavia dates from 1359, when the Duke Galeazzo Visconti, after the capture of the latter town, caused such a line to be opened; and reference is made, in a document which is dated 1411, to the "new canal which goes to Pavia." This line, constructed before the invention of locks for navigation, could, however, have been only for irrigation. Between 1473 and 1475, the canal was rendered navigable from Milan to Pavia, but it was not long before neglect on the part of the magistrates, in failing to check unauthorised encroachments on the supply of water by private parties, led to the cessation of navigation. In 1564 the reopening of the canal was agitated, but the proprietors of the adjoining lands, and the cities of Milan and Pavia, on whom conjointly it was proposed to throw the burden of the expense, objected to the work on the plea that they did not want it for irrigation, while for navigation the canal of Bereguardo was sufficient. In 1597 the project was revived, and the engineers Meda and Romassi estimated the expense at 80,000 scudi, or about £15,000—a sum equal to perhaps six times the same amount at the present time. The works were actually undertaken, and the government disbursed about 50,000 scudi, proposing to call upon the adjoining landed proprietors for the remainder of the estimate. Again, however, this resource failed, and the contract with the engineers was broken. A record of this transaction is preserved to the present day, in the name of the lock nearest Milan, which continues to be called the *Conca Fallata*—the *Lock of*

Failure, and marks the point at which this early effort terminated. The object of linking Milan directly with the Po, was, however, too important to be long left in abeyance, and the question was a third time raised by the Spanish government in 1601, which decreed the sale of grants of water from the Muzza canal to the extent of 25,000 crowns for the benefit of the proposed canal. The times, however, were too troubled for the project to be then carried into effect. In 1646 plans for the canal, in great detail, were submitted by the engineer Bigotti, and a company was formed a few years afterwards to supply the necessary funds; but an essential condition insisted on by the shareholders was, that government should resume the interrupted reforms of Soldati, and remodel the whole of the outlets of the Naviglio Grande. On this rock the scheme split, for the government either would not or could not comply with the condition prescribed, which was essential to the security of the company; and so matters remained as they were until the latter end of the eighteenth century, when the Austrian government commenced very earnestly to complete the line: but the influence of the French Revolution reaching Italy about this time, all works of peace were suspended for many years afterwards.

The following decree, published on the 21st June 1805, fixes the period of the commencement of the present magnificent canal, by which the problem of connecting Milan with the Po was finally solved, after having been agitated with results more or less imperfect for the space of nearly four centuries and a half:—

"Napoleon, by the grace of God, &c., Emperor of the French and King of Italy.

"We have decreed, and we decree as follows,—

"1st. The canal from Milan to Pavia shall be made navigable. The project shall be submitted before the 1st of October, and the works shall be so distributed as to be terminated within the space of eight years.

"2d. Our minister of the interior is charged with the execution of the present decree. NAPOLEON.

"MANTUA, 20*th June* 1805."

The immediate consequence of this decree was the formation of a Commission in Milan, charged to prepare all the necessary details of the project for submission to the Emperor. Their first report was completed by the 21st October 1805, and recommended that the supply for the new canal should be drawn from the Ticino, and carried to Milan by means of the existing channel of the Naviglio Grande. There was considerable variety of opinion as to the measures best calculated to secure the increased supply, but it was finally decided that the escapes should be carefully repaired, so as to check the wastage previously existing, that the bed of the Naviglio should be deepened from nine to twelve inches, and that, when necessary, the temporary dams of the Ticino should be extended; and experience has shown that nothing further was necessary. The original supply thus secured was 150 *oncie magistrale*, or 225 cubic feet per second; but this was subsequently found to be more than the canal could conveniently carry, and it was reduced to the present discharge of 213 cubic feet. The works, as indicated in the first project prepared by the celebrated Brunacci, a standard authority on hydraulics in Italy, and the engineers Guisani and Guidici, included 12 locks, with 14 bridges across the canal; in addition to the canal

bridges, 16 others for the embanked roadway along the canal, 8 aqueducts of various dimensions, 2 tunnels, 38 siphons, and no less than 122 works of different kinds, required solely for the maintenance of the pre-existing state of irrigation in the country through which the canal was to be carried.

The works were commenced in 1807, and for some years afterwards were carried on with great vigour. The military and political events connected with the fall of Napoleon, and the restoration of Lombardy to the dominion of Austria, caused a temporary interruption to the progress of the canal; but on the final settlement of European affairs, the existing government resumed and perfected the original project. On the 17th of September 1819, in presence of the Archduke Rainer, Viceroy of Lombardy, and of all the great officers of the State, the canal was opened for navigation and irrigation; and it has continued since that time to be a line of the highest utility in both respects, being certainly one of the finest works of its class ever executed.

The Naviglio Grande terminates under the walls of Milan, near the Bridge of the Trophy. At this point the head of the canal of Pavia is established. From thence it follows the great road to Pavia as far as Benasco, whence it turns slightly to the left, and pursues a direct course to the city, round the walls of which it makes a circuit, and then falls into the Ticino.

The distribution of the slope of its bed, and the positions of the twelve locks by which the excess of this slope is disposed of, are shown in the following Table :—

	Distance in miles.	Total fall in feet.	Fall p. mile in feet.	Fall of Locks.
Flooring of the bridge of the Trophy, near the dock of the Porta Ticinese,	0.00	0.00	0.0	0.0
1. Fall of the Conchetta, . .	0.48	0.00	0.00	5.76
2. „ Lambro, . .	1.36	1.92	1.4	15.02
3. „ Rozzano, . .	3.34	2.88	0.8	11.76
4. „ Moirago, . .	0.86	1.28	1.5	5.44
5. „ Casarile, . .	3.94	2.43	0.6	15.68
6. „ Nivolto, . .	2.22	1.28	0.5	11.44
7. „ Torre del Mangano,	2.22	1.28	0.5	14.40
8. „ Cassinino, . .	1.92	1.47	0.7	15.68
9. „ Porta Stoppa, of Pavia,	2.66	1.53	0.6	14.40
10. „ Bastione Botanica (double), . .	0.51	0.00	0.0	12.40 12.40
11. „ Porta Cremona, (double), . .	0.18	0.00	0.0	12.40 12.40
12. „ Ticino, . . .	1.36	0.00	0.0	10.80
Bank of the Ticino, . . .	0.12	0.00	0.0	0.0
Totals and averages, .	20.07	14.07 169.98	6.6	169.98
		184.05	0.82	

From these data it appears that part of the channel of the canal has no slope whatever, and on the remaining portion the inclination is very nearly ten inches per mile. The total fall from the Bridge of the Trophy to the ordinary level of the Ticino being 184.05 feet, we find 14.07 feet absorbed by the inclination of the bed, and 169.98 feet disposed of by the twelve locks.

The breadth of the canal at the water-line is 35.36, and at the level of the top of the banks 38 feet. In the immediate vicinity of Pavia, where the boats collect, the breadth is gradually increased to 45 and 65 feet, while the dock at the city has a breadth of 213 feet, giving abundant facilities for the navigation. The height of water at the head, which secures the full supply of the canal, is 3.84 feet in summer, and 5.28 in winter, when

an additional quantity equal to about 90 cubic feet per second is admitted into the canal.

The principal works are, first, the twelve locks for the passage of boats, the construction of which will be illustrated in ample detail hereafter. In this general description I need only mention that they are admirably built in masonry of cut stone or brick, with floorings of flagstones or boulders. Each has two chambers, one being fitted with gates and sluices, and the other being a simple regulating channel, by which the level of the water above the lock is duly maintained, and the supply necessary for the lower portions of the canal is transmitted independently of the action of the locks. The following Table shows the general dimensions of the locks :—

	Fall.	Chambers. Length.	Chambers. Minimum breadth.	Chambers. Maximum breadth.
	Feet.	Feet.	Feet.	Feet.
1. Lock of the Conchetta, ...	5.76	164.	16.58	20.51
2.	15.02	173.8	17.68	17.68
3.	11.76	161.9	16.58	20.51
4.	5.44	161.6	16.58	20.51
5.	15.68	170.6	16.58	20.51
6.	11.44	167.3	16.58	20.51
7.	14.40	183.7	16.58	20.51
8.	15.68	170.6	16.58	20.51
9.	14.40	183.7	16.58	20.51
10.	{ 12.40 / 12.40 }	341.2	17.04	20.51
11.	{ 12.40 / 12.40 }	351.	17.04	20.51
12.	10.80	239.	17.04	20.51

To facilitate cross-communication, each lock has a bridge of stone masonry attached to it. When I visited the canal of Pavia, I found only one guardian at each of these locks, who, with the assistance of a boatman, managed the whole of the machinery with the most perfect ease.

There are four intermediate bridges, and seven station-

houses placed at intervals along the canal banks for the use of the establishment. Mills are established at the escapes of the locks, and are rented on behalf of the government.

The other principal works are, the aqueduct across the river Lambro, of which the right side forms an escape for regulating the supply of the canal; three other escapes, having seven sluices, for the same purpose; and 75 smaller aqueducts and siphons for the passage of irrigation channels, which are private property. Of these, 62 existed before the canal was constructed, and 13 have been made subsequently. The principle on which the expense of these has been distributed, was to provide, at the cost of the government, for the passage of all channels existing when the canal was constructed, and to require the proprietors to pay for all made afterwards. The Government of India has introduced the same principle, and I think it is the fairest that could be adopted in such cases. The aqueducts and siphons are built of brick or cut stone, and vary in length from 80 to 120 feet, according to circumstances. The number of siphons is 65; and the heights above the level of the surface of the canal, at which they deliver the water passing through them, vary from 3½ to as much as 12½ feet, the breadths range from 3 to 14 feet, and the whole carry water for irrigation. For the collection of drainage water, and its passage across the line of the canal, there are 10 aqueducts of the ordinary form.

Except in the vicinity of the locks, the bed of the canal is formed by the natural soil; the banks are protected, where necessary, by revetments of masonry and lines of piling, the length of which on both sides is nearly 30 miles.

There is a roadway on each bank of the canal 20 feet

in width, admirably constructed and protected by stone parapets, which form a very handsome and efficient boundary to the works. The material employed is a white-coloured granite, which is easily wrought, and is not expensive, the parapets costing about 10s. per running yard.

There is only one hydrometer on the canal, which is placed at the lock of the Conchetta ; but the ordinary regulation of the supply is effected by observation of the heights on the sills of the locks. The admission of water at the head is controlled by reference to the hydrometer of the Naviglio Grande near the Bridge of the Trophy, where the outlet for the canal is established.

The permanent establishment of the canal of Pavia consists of 14 guardians, who have districts under their charge varying, according to the importance of the works, from 2 to 4 miles in length. The guardians at the upper and lower extremities of the canal are charged with the inspection of the boats, for which the fixed dimensions are 105 feet in length, 13 in breadth, 2.4 draught, and 3.84 in depth. The guardians receive salaries averaging £22 per annum.

The clearances of the canal from deposits and aquatic plants are made twice a-year: in spring, between the 3d of March and the 1st of April; and in autumn, between the 17th and 24th of September. The spring clearance is a thorough one, involving the entire removal of the sandy and gravelly deposits which take place in the bed, not only from the introduction of the turbid waters of the Lambro, Olona, and Sevese, but also from the sewerage channels of the city of Milan, part of the contents of which are thrown into the canal of Pavia. The rich deposits thus formed nourish masses of aquatic plants, which of late years have caused such serious inconvenience,

as to have suggested the propriety of paving the entire line of the canal with flags of granite—a proposal which will probably be carried into effect, as both the section of the bed and the proper distribution of the water for irrigation and navigation are at present interfered with seriously.

The annual expense of maintaining the canal of Pavia amounts to £1392, 12s., and the income derived from it by the government does little more than cover this outlay. With reference to the latter point, it must, however, be noted that, by the sale in perpetuity of about 115 cubic feet per second of the supply of the canal, government has realised a capital of nearly £25,000, which, at the ordinary rate of profit from irrigation works, represents an annual income of about £1100, in addition to £1875 which is the present income from the canal.

The total cost of constructing the modern canal of Pavia was nearly £296,875, or £14,800 per mile. As the total income from all sources does not exceed £3000, of which nearly £1400 are absorbed in the annual expenses for repairs and establishment, it appears that this fine work returns to the government, as nearly as possible, one-half per cent on the capital sunk in its construction. In undertaking such a work, it is, therefore, clear that the government merits the credit of pecuniary disinterestedness; for the benefits derived from it appertain almost exclusively to the agricultural and commercial classes of the community.

The volume of the canal is, as already noted, 213 cubic feet per second in summer. On the first construction of the works, from 225 to 240 cubic feet were thrown into the channel; but the contraction of the section by deposits and aquatic plants caused so much inconvenience that a reduction of volume was found to be absolutely necessary.

Of the present summer supply 138 cubic feet are distributed for irrigation from 25 outlets, of which 23 are regulated by the *modulo magistrale*, while 2 only are unregulated. The remainder of the summer supply, or 75 cubic feet per second, is reserved to secure the navigation of the line. The irrigation outlets are distributed on both banks, there being 6 on the right and 15 on the left. The discharge from each varies from about 3 to 9 cubic feet per second, and no single outlet is allowed to have a larger discharge than the latter of these quantities, for a reason which will appear when the properties of modules of different dimensions come under discussion. Of the summer supply 115 cubic feet are disposed of in perpetuity, and 23 cubic feet only by annual agreements.

The extent of irrigation from the canal in summer amounts to 9550 acres, being 69.2 acres for each cubic foot of discharge per second. In winter the 225 cubic feet which are then available irrigate 294 acres of marcite, giving 1.3 acres for each cubic foot.

The price of irrigation is so nearly the same as on the Naviglio Grande that I need not repeat the details here; but I may mention that, when any difference exists, the cost is rather less on the canal of Pavia than on the main line.

There is greater loss by filtration on this line than on any other in the Milanese. I could not help noticing, when I saw the works, the large quantities of stagnant water which showed themselves outside the banks, evidently supplied by filtration from beneath. The soil is exceedingly light and porous; and as the level of the water is in many places above that of the adjoining country, the hydrostatic pressure had so operated as to generate swampy tracts of considerable extent along the line, which looked both unhealthy and untidy. The masonry revetments, though extending for three-fourths

of the length of the canal, do not seem to have checked this evil, which, however, will cease if the plan of paving the channel is ever carried into effect. Meanwhile, the only remedy is to connect the swampy tracts by drainage cuts with the river lines or irrigating channels in the vicinity at lower levels, and so to allow the water to flow off, instead of stagnating under the banks, as it was when I passed along them.

The Naviglio, or Fossa Interna of Milan, is the connecting link between the canals of the Ticino and the Adda; but as it is directly connected with the Canal Martesana, it will be more convenient to describe it in the next chapter.

The extent of irrigation from the Lambro, Olona, and the smaller streams of the Milanese, may, however, be adverted to here. From the most westerly of the series, the Olona, an area of 2395 acres, is irrigated in summer, and about 50 acres in winter. By the Lambro, from the junction of the escape-lines of the small lakes of Pusiano, and Alserio to Melegnano, where irrigation from this river terminates, 15,286 acres are watered in summer, and about 350 acres in winter. From the other small streams traversing the western portion of the Milanese, the area of irrigation may be approximately estimated at about 2000 acres in summer, and 250 in winter.

No. IX.

No. IX.—Historical and Descriptive Data connected with the Canals of the Ticino.

	Supplying river.	Date of construction.	Position of head-works.	Works. Bridges.	Works. Aqueducts, dams, &c.	Works. Falls.	Works. Irrigation outlets.	Length of channel in miles.
1. Naviglio Grande, .	Ticino	1178	Tornavento	10	22	..	120	30¾
2. ,, Bereguardo,	Naviglio Grande	1460	Abbiate-grasso	3	..	11	18	11¼
3. ,, Pavia, . .	Do.	1359 1807	Near Milan	17	86	12	25	20
Totals, . .	—	—	—	30	108	23	163	62

No. X.—Agricultural and Financial Data connected with the Canals of the Ticino.

	Discharge in cubic feet per second.	Area of land irrigated in acres.	Price of Water. By fixed opening per cubic foot per second.	Price of Water. By surface irrigated per acre.	Annual expenditure in pounds sterling.	Annual income in pounds sterling.	Area of irrigation in acres per cubic foot per second.	Annual indirect returns in pounds sterling.
			£		£	£		£
1. Naviglio Grande, .	1851	93,440	7 to 13	4/	1700	1796	61.8	60,000
2. Bereguardo, . . .	156	10,400	—	—	—	—	66.6	6,240
3. Pavia, ...	213	9,550	—	—	1392	1875	69.2	5,730
Lambro, Olona, &c.,	240	20,161	—	—	—	—	84.0	12,108
	2460	133,571	—	—	3092	3671	70.4	84,078

SECTION IV.

CANALS OF THE RIVER ADDA.

1. CANAL MUZZA.

One of the provisions of the treaty of Constance, concluded in 1183, was to guarantee to the Free Cities of the Lombard League, on the part of the Emperor of Germany, the full enjoyment of all the waters within their respective territories. Hence, for some time after this date, the municipal authorities of each town regulated the grants and distribution of the public waters without external interference of any kind.

About the close of the twelfth century there existed a canal of irrigation, which bore the name of the Roggia Muzza. It was then, however, supplied solely by the water from springs or drainage derived from the district of Lavagna and its neighbourhood, to the north-east of Milan. The original proprietors of the canal were the Administrators of the Hospital Broglio in Milan, and the water was employed in irrigating not only the lands belonging to this charity, but also considerable tracts, the property of the cities of Milan and Lodi. About the year 1200 the canal was considerably enlarged and extended, at the expense of the hospital. Farther supplies from springs and drainage were thrown into it, but as yet it was not connected with the river Adda.

The experience of the admirable results of the opening of the Naviglio Grande stimulated the authorities of Milan to project new works of the same class; and in 1220, such arrangements were made with the Hospital of Broglio as admitted of the construction of a grand canal

from the Adda, near Cassano, which, occupying the old bed of the Roggia Muzza as far as Paullo, was carried onward through the province of Lodi. In 1239 a junction between the Muzza and the Northern Lambro was effected by means of the Addetta, or Little Adda, which discharges the double function of an irrigating and an escape line. It joins the Lambro at Melegnano, and was executed at the joint expense of the city and hospital above mentioned. It appears, however, that up to 1256, at least, the proprietory right to the canal continued to be vested exclusively in the Administrators of the hospital, and the Magistracy of Milan assumed no power of interference in the sale or division of the water. The inhabitants of Lodi, however, were ill content with existing arrangements, for the hospital authorities had constructed a dam at Paullo, which intercepted the stream at that point, and thus deprived them of all means of irrigation. They endeavoured forcibly to destroy the dam, and thus established a quarrel with their neighbours of Milan. In August 1285, the latter city sent an embassy of four distinguished citizens to adjust the dispute, and the result was the full acknowledgment of the prior claims of the hospital, and an undertaking, on the part of the Municipality of Lodi, to repress all infringements on these. A year later, Ottone Visconti, Archbishop and Signor of Milan, addressed a letter to the Podesta, Capitano, Council, and Commune of Lodi, proposing to enlarge the channel of the Muzza at the joint expense of the two cities and the hospital, and so to divide the increased supply as to meet the wants and wishes of all parties. This conciliatory proposition was accepted, and on the 23d October 1286, the necessary agreements were entered into for the execution of the new works and the distribution of the expenditure. Shortly afterwards the works were

completed, and such measures as the state of hydraulic knowledge at the time suggested were adopted for dividing the enlarged volume the canal now carried. That these measures were imperfect is certain, and that the two communities were farther disposed to quarrel whenever they could, is only what we might expect from our knowledge of the feelings of intense dislike with which these petty republics regarded each other, and, as every traveller in Northern Italy must have observed, continue at this moment to do. The natural consequence of this state of affairs was an incessant series of disputes between the Milanese and the Lodigians; and I must frankly confess that I have never read a more wearisome record than the "*History of the Muzza Canal*," from the end of the 14th to the end of the 17th centuries. It is, without exaggeration, nothing more than one dreary course of wrangling, which no interference of Princes or Magistrates could arrest. Decrees innumerable were published from year to year, to which no one seems to have paid the slightest attention; and though the Dukes of Milan appear constantly on the scene, their efforts had no permanent effect in stilling the troubled waters. I have gone over the entire series of discussions, as recorded in minute detail by Bruschetti; but as I find neither useful principles illustrated, nor practical details eliminated by them, I am sure I shall be excused from entering at any length upon them here. I shall only, therefore, sketch very rapidly the history of the canal up to the present time.

The importance of possessing the proprietory right over such a volume of water as was carried by the canal Muzza, led to constant efforts on the part of the Dukes of Milan, whether of the Visconti or Sforza families, to wrest this from the Municipalities of Milan and Lodi, and the Administrators of the hospital Broglio. Some very gross

attempts were frustrated; but ultimately the despotism of the princes prevailed, and in 1499, Ludovico Sforza appropriated to himself the exclusive proprietorship of the canal, reserving only the rights of the hospital. In the early part of the sixteenth century, when France held the Milanese, the charge of the canal was vested in a royal commission, and all expenses connected with the works were defrayed from that time forward by the State. The Adda, at this period, threatened to break in upon the course of the canal between Melegnano and Lodi, and great works were required to divert the river from its course, as, had the inroad occurred, it is probable that the canal channel would have become the permanent bed of the stream, and all the works been swept away. A system of dikes and spurs on a large scale averted this calamity; and from that time to the present day there have been no formidable accidents affecting the works.

The evils arising from the extremely imperfect regulation of the irrigation outlets, were not less marked on the Muzza than we have already seen them to have been on the Naviglio Grande; and equal difficulty was experienced in subjecting them to some better control. The outlets arranged themselves into three classes. 1. *Free*, for which the proprietors paid no rent whatever; 2. *Taxed*, for which annual rent was paid, according to tariffs fixed from time to time by the authorities in whom the charge of the canal was vested; and, 3. Outlets for which the payment was matter of private agreement. An attempt was made in 1574 to apply to all of these that system of regulation, by the use of the *modulo magistrale*, which had been introduced on the Naviglio Grande. All the old outlets were found to be wretchedly constructed, most of them being merely of wood, and the rest of bad masonry. Their discharges were consequently most irregu-

lar, though almost invariably in excess of the limits prescribed in the original grants. The proprietors, of course, resisted strenuously all means of regulation — claiming rights of property which could not be interfered with even by the State; and the hospital of Milan especially denied the right of the government to limit its consumption of water in any way whatever. As the opposing parties were powerful, the progress of reform was very slow. It required fifteen years to effect the mere reconstruction in masonry — with fixed superficial dimensions — of the different outlets. In 1624 the engineers of the government had remodelled forty-five outlets, though in an imperfect manner; and others, the precise number of which is not specified, were regulated by amicable agreements between the proprietors and the farmer, or government contractor for the rent of the canal, a functionary to whom about this time the collection of the revenue had been committed. Between 1688 and 1700, many inspections of the canal were ordered by the government, with the view of carrying out the project of reform; but the usual fate of failure attended them all.

The contract for the revenue having expired in 1706, the government was obliged to bind itself to proceed at once to the regulation of the remaining outlets, before any one would come forward to supply the place of the retiring farmer. It gives a strange illustration of the condition of the governing authority of Spain in the Milanese, to find that it was wholly unable to fulfil its obligations, and had to sustain an action at law, raised against it by the farmer, who failed in his contract, and claimed an indemnity for his losses in consequence of the breach of that promise which had induced him to undertake the task of collecting the revenue. More commissions of inspection, more voluminous reports, and the

same uniform results to all, carry on the history of the canal through the eighteenth and nineteenth centuries to the present time, when the regulation of the outlets remains still very imperfect; and it is not probable now that any further attempts will be made by the government to interfere in the matter.

The head of the Muzza canal is established on the right bank of the Adda, opposite the little town of Cassano. The supply is obtained by means of a dam of masonry carried obliquely across the river, which, when I saw it in March 1851, had turned the entire volume of the river into the canal-bed, forming there a noble stream. The line of the canal is crossed at various points by rude dams for raising the water so as to supply the irrigation outlets. Of these there are thirteen permanent and two movable, the former acting as imperfect falls in regulating the excessive slope of the bed. The following details will show the length and inclination of the canal:—

	Distance in miles.	Total fall in feet.	Fall per mile in feet.
1. Cassano to Bridge of Lavagna, . .	6.95	48.78	7.0
2. Lavagna to the Dam of Muzzetta, . .	4.08	19.50	4.7
Fall of the dam, ...	—	4.48	—
3. From the dam to Paullo, ...	0.24	1.28	5.3
4. Paullo to Melegnano Road, . . .	7.13	29.64	4.1
Fall of five dams in this tract, . .	—	23.26	—
5. Melegnano Road to S. Angelo Road, .	3.34	13.24	3.9
Fall of seven dams in this tract, . .	—	33.10	—
6. S. Angelo Road to Casal-Pusterlengo, . (In this tract are two movable dams or long gates opened during floods.)	4.64	12.24	2.6
7. To junction with the Adda, ...	8.99	42.37	4.7
	35.37	227.89	6.4

The length of the canal, properly so called, is 23½ miles. The upper part of the channel from Cassano to Lavagna,

a distance of nearly 7 miles, is exclusively the property of the State, and is maintained solely at its charge. The lower portion from Lavagna to the head of the escape to the Adda, about 16 miles in length, is maintained at the expense of the proprietors through whose lands the line passes, but the executive charge and general control are vested in the government engineers. The line from the head of the escape to the Adda, or the Weir of Massalengo-Lodigiano, is intended merely for the passage of the surplus waters, and is about 12 miles long. The upper escape, or the Addetta, which falls into the Northern Lambro, is 8 miles in length ; thus making the entire length of the Muzza canal, including the escapes, nearly 43½ miles.

A glance at the table of levels will show how very rapid the slope of the bed is. On the entire length of the main line there is a total fall of 227.89 feet, of which 61.16 feet are disposed of by the dams across the bed, and 166.73 feet are distributed along the channel, giving an average slope for this of 4.7 feet per mile. As a natural consequence of the rapidity of the fall, the canal assumes all the appearance of a river, and its ordinary name in the country is the *Fiume Muzza.* Its breadth at Cassano is 160 feet, and a few miles lower, at the Bridge of Saint Bernard, it is only 90 feet. Its section, indeed, throughout its entire length, is extremely variable, ranging from 80 to nearly 180 feet.

For about 3½ miles from its head, the canal-bed is carried along the face of the high bank bounding the river on the right, and is sustained where necessary, by retaining-walls of masonry. In advance, the channel is generally just below the surface of the ground, with occasional excavation and embankments. The principal works, in addition to the dam across the river,

are—1st, The great escape-weir near the head, having a length of 767.55 feet, and solidly constructed in masonry. 2d, Four regulating escapes, also near the head, having 42 sluices through which the flood waters find their way to the Adda. 3d, The bridges of Cassano, St Bernard, Truccozano, and Lavagna. 4th, The regulating head of the Addetta and its attached bridge, with an aqueduct for the passage of the canal Friliana. The Addetta regulator has 9 sluices. 5th, The Paullo regulator, with 6 sluices, which is intended to give command over the supply passing to the lower portion of the canal. 6th, An escape with a single sluice, for drainage purposes during the period of annual clearance. 7th, Nine regulating profiles, formed of piles carried across the canal-bed, and protected by masonry wing-walls, intended to define the section of the canal-bed, and to regulate the excavations during the clearances. 8th, About 9½ miles of revetment-walls, to protect the banks at those points exposed to the action of the current. 9th, Two station-houses for the establishment, stores, tools, &c.; one at Cassano, the other at Paullo. 10th, Five hydrometers for regulating the canal supply, of which the most important is at St Bernard, near the head. These are each formed of a pillar of granite, in which a graduated scale of white marble is imbedded, and are in daily use, particularly at the time when the waters are readmitted into the channel after the annual clearances, when considerable delicacy of management is required to adjust the supply to the gradually increasing demand. All these works are maintained at the expense of government; in the lower part, such works as exist are intrusted to the care of the private proprietors.

As on the canals of the Ticino, there are two annual clearances, one lasting 25 days in March, and the other

eight days in September. Such repairs as are necessary to the masonry works and banks are also executed at this time by the government contractor, who holds his contract for maintaining the canal during nine years. The canal is closed for repairs by means of a temporary dam of fascines, &c., thrown across the bed at the bridge of St Bernard, which is usually effected at a cost of about £30. Every ten years the dam is placed at the mouth of the canal; and as it has to be constructed there of larger dimensions, and in a stronger manner, than usual, it is proportionally more expensive, costing from £80 to £100.

I have had some little difficulty in arriving at a correct estimate of the actual volume of the Muzza. The latest detailed estimate I have had access to, is given by Bruschetti ("*Irrigazione*," p. 464), and bears date 1829. In this the discharge of each of the 75 irrigation outlets from the canal is given separately; and as the unity of measure on this canal is the *oncia* of Lodi, the results are stated accordingly. The *oncia Lodigiana* is to the *oncia Milanese Magistrale* as 0.52 to 1; and hence the absolute value of the former may be taken, for all practical purposes, at 0.75 cubic feet per second. According to the measurement above adverted to, the entire volume of the canal employed in irrigation is 2851 *oncie Lodigiani*, or in English measure 2138.25 cubic feet per second. Other authorities make this volume equal to 2212.5; but a very slight difference in the measurements or formulæ for calculating the discharges would easily account for the small excess of the latter. If the mean of the results be taken, and the volume is estimated at 2175 cubic feet per second, we shall not be far from the truth. This, however, it must be noted, is the quantity drawn from the canal for irrigation, and not the total

discharge. No measurement of the latter seems to have been executed since 1786, and it then amounted to 2652 cubic feet per second, the irrigating volume being the same as now. There is, therefore, a difference of 477 cubic feet per second, which is lost by evaporation, percolation, leakage at escapes, or waste. This gives a rate of loss equal to about 13½ cubic feet per second for each mile. It must be noted, however, that while the irrigating volume is tolerably constant, the actual discharge of the canal is very variable, owing to the irregularities of the surface-level of the Adda, which render necessary a constant use of the escapes. I attach very little practical value, therefore, to the estimate of the total discharge, or the deduction of the rate of wasteage per mile made from it. I may mention here, to illustrate the gradual extension of the canal, that in 1553 its irrigating volume was only 1119 cubic feet per second.

The present irrigating supply of 2175 cubic feet is distributed by 75 outlets, whereof eight are in the upper part of the canal between Cassano and Lavagna, having a total discharge of 487 cubic feet, and 67 in the lower portion between Lavagna and the weir of Massalengo, whose united discharge amounts to 1688 cubic feet. In relation to the revenue, an examination of the table of 1829 gives the following results :—

	No.	Discharge. C. F. per sec.
1. Free outlets, ...	19	477
2. Outlets regulated by private agreement,	6	172.5
3. Taxed outlets, ...	50	1525.5
Total, .		2175.

From the two latter classes of outlet, government derives an annual revenue of £1396, 12s. 6d., or very nearly 16s. 6d. per cubic foot per second—an astoundingly low rate, giving only about 3d. per acre ! In fact, the govern-

ment is paid according to the ancient tariffs which were in existence when the outlets were first granted, and it has refrained, with singular self-denial, from increasing its demand with the increased value of the water, which in all parts of the Milanese is just about twenty times greater than the amount shown above.* Some of the outlets are of great size: the three which bear the names of Cadogna, Muzzetta, and Cavallera-Crivella, absorb very nearly one-fifth part of the entire supply of the canal. The largest of all, the Muzzetta or Little Muzza, has a discharge of 144 cubic feet free from all charge. These minor branches, of which there are 41 on the right bank and 34 on the left, are small canals supplied with numerous masonry works, and administered by their respective proprietors as they think best; for here, as elsewhere in Lombardy, the government surrenders all control over the water the moment it enters the private channels. Three only of the outlets are noted in the table as regulated by the Milanese module, all the rest which are regulated at all being so by that of Lodi; but it is evident, from examining the column which shows the height of water above each outlet, that the whole system is most imperfectly enforced.

The area of irrigation from the Muzza amounts in summer, according to the latest data, to 182,500 acres, being 83.9 acres for each cubic foot of discharge per second. In winter, the extent of *marcite* irrigated amounts to 2750 acres, or 1.27 acres per cubic foot. The waters of the canal are further employed in supplying motive force to 62 corn-mills, 30 rice-mills, 26 oil-mills, a saw-mill and foundry; in all, 127 water-wheels.

* In Northern Italy, as in Northern India, however, the land-tax on properties possessing facilities for irrigation is considerably higher than in other cases; so that the government derives from this source a considerable access of revenue due to its canals of irrigation.

The annual expenditure on the seven miles at the head of the canal, under the exclusive charge of government, amounts to nearly £750. The two guardians at Cassano and Paullo, who constitute the whole permanent local establishment, receive about £22 each, making the total expenditure £794 per annum, or about £113 per mile.

The annual income from water-rent I have already stated to be £1396, 12s. 6d., to which a further sum of about £80 for mill-rent and other trifling items must be added, making the whole about £1476 per annum. A net income of about £662 is therefore all that the Austrian government receives from this great canal, which has increased the rental of the districts through which it flows by at least £100,000 a-year—and in reality, I believe, by a much larger sum—while the value in capital of the waters is equal, according to the current rate, to little less than half a million sterling.

What the precise expenditure by private parties on the lower part of the canal may be, I had no means of ascertaining; but as the whole of the great works are maintained by government, it must be but trifling.

Before leaving the Muzza canal, I must take the opportunity of correcting a misapprehension on the part of the Lombard historians and writers on irrigation. They are under the impression that the Muzza is the largest canal of irrigation in the world. It is no more than justice to the British government in India to mention, that the existing canal west of the river Jumna has a volume equal to that of the Muzza, and a length of course more than ten times greater. Its area of irrigation is nearly five times that of the Muzza; its works are far more numerous — in all respects equal, in some decidedly superior, to those of the Lombard line. Instead of 75 outlets, it has upwards of 670; and

instead of half-a-dozen bridges, it has 214; and so on with other works. Finally, its gross rental, instead of £1400, is upwards of £30,000 a-year; while it has secured to the agricultural community, benefits fully equal to those obtained from the Muzza. With the Ganges Canal the greatest in Lombardy will stand no comparison. The volume of water of the Indian line is thrice that of the Muzza—its area of irrigation eight times—its length thirty times—its estimated annual income a hundred times greater; and there are no works, either on the Muzza or any other canal I saw in Northern Italy, which approach in magnitude to those now in progress in Northern India.

I have thought it right to say these few words on the comparative dimensions of Italian and Anglo-Indian canals, because I found that nothing whatever was known of the latter among the intelligent engineers of Lombardy and Piedmont. Nor do I wonder at this, for in England there is nearly equal ignorance; and I cannot refrain from saying that I think the Government of India does itself the most grievous injustice by taking no measures whatever to convey to the public authentic information regarding those great works, which, with equal advantage to its subjects and itself, it has been occupied in developing vigorously during the last thirty years. The impressions of the character of the British government in India, among intelligent foreigners, I found to be of a very unsatisfactory kind; and it was gratifying neither to my national nor personal feelings, to have to rectify the idea that we had done little or nothing to improve the condition of the people. As men's minds in Northern Italy were thoroughly familiar with the nature and influences of works of irrigation, I found that even the imperfect accounts I was able to give of what the English in India

had already effected in this department, were productive of good. The constant commentary on the information given was, however, "why are no accounts of such works communicated to the world?" And I earnestly hope it may yet be considered desirable that a worthy record of them should be made.

II. CANAL MARTESANA AND NAVIGLIO INTERNO, OR INTERIOR CANAL OF MILAN.

Upwards of two hundred years after the construction of the first canals from the Ticino and the Adda, the country to the north-east of Milan, forming part of the ancient district of Martesana, made known its want of irrigation. A second great canal from the latter river was consequently projected to satisfy this demand; and, in 1457, the necessary works were undertaken at the public expense, and under the orders of Duke Francesco Sforza I. Commencing under the high cliffs on which the picturesque old castle of Trezzo is situated, the line was completed within a few years to the suburbs of Milan, and at first bore the names of the Naviglio Piccolo or Ducato, or finally Martesana, which last has now become its distinguishing title. Very soon after the completion of the line, we find detailed regulations issued for the due application of that "Right of Passage" in the distribution of its waters, which secured to those receiving grants, the power of carrying their channels across the lands of other parties. In 1465, the Duchess Bianca Maria Visconti published a decree, under date the 11th of September, directing that, in all such cases, arbitrators should be appointed in equal numbers by the proprietors of the land and of the water, who were to receive the opinions of skilful men (*periti*) as to the compensation to be paid for

the land, and the direction the water-course was to take, so as to cause the least possible damage. The award of this tribunal was to be final; and it is interesting to find that this right was now so firmly established, and so clearly defined.

About five-and-thirty years before the commencement of the Naviglio Martesana, the discovery of the principle of the lock for navigation had been made, and one at least was actually in existence, connecting the Naviglio Grande with the interior canal of Milan. Hence the Martesana Canal was not intended to be, like the Muzza, purely a canal of irrigation, but of navigation also, and two locks were accordingly established upon it, one at Gorla, the other at Cascina di' Pomi, by the use of which boats could pass to the suburbs of the city. Beyond these, however, the canal was not yet carried; and as the ultimate junction between the Ticino and the Adda was effected some years afterwards through the medium of the Naviglio Interno, the history of that work becomes now interwoven with the present narrative.

In the historical sketch of the Naviglio Grande, it was stated that this line, on its first construction at the close of the 12th century, was connected with the ditch which then surrounded the fortifications of Milan. On the reconstruction and enlargement of the city in 1183, after its destruction by Barbarossa and his Italian allies, this ditch, formerly without, became included within, the new boundaries, and, still supplied with water from the grand canal, formed the Fossa Interna, or interior canal of Milan.

The history of this canal has a curious interest in connection with the archæology of engineering. The locks on the line were *probably* the earliest instances of the application of this kind of work for purposes of navigation. A brief notice on the subject of the invention of this most

useful apparatus, by Signor Elia Lombardini (*Not. Nat. e Civile*, p. 177), may be interesting.

In the *Antichità Longobàrdiche* (vol. ii. p. 108), a document belonging to the Monastery of Chiaravalle, dated 1439, is quoted, wherein distinct reference is made to the "Conca di San Maria in Viarenna," * as connecting the Naviglio Grande with the Fossa Interna. This work was constructed by order of the Duke Fillippo Visconti, to facilitate the transport of the marble for the Duomo, which was brought by the Ticino and Naviglio Grande from the quarries on the Lago Maggiore. Another document, under date 1445, preserved in the Ambrosian Library of Milan, and quoted in the work above referred to, mentions the improved Naviglio Interno under the name of "the new Ducal Canal," and specially adverts to the lock upon it.

By comparing these documents with others, bearing date 1400, indications are obtained of the method by which the passage of boats was effected before locks were introduced. This process, as described by Lombardini, I do not exactly comprehend; but at best, it was tedious and rude in the extreme, and seems to have involved the lowering of the level of the Naviglio Grande to that of the Fossa Interna, by the discharge of the water in the whole of the lower portion of the former channel. The two canals were separated from each other by a dam about

* It is a curious point of interest connected with this lock to find it recorded, on a marble slab in its immediate vicinity, that the revenue derived from the passage of boats through it was granted by Ludovico Sforza to the Duomo of Milan —"Anno quo Beatrix Estensis conjux decessit 1497"—that Beatrice d'Este whose beautiful tomb is one of the ornaments of the gorgeous Certosa of Pavia, and whose personal history is like a gleam of sunshine in the troubled career of her ill-fated husband. It may have been before his marriage to this accomplished woman, but it is certain that some of the grants of water from the public canals made by Ludovico are plainly stated to be in return for favours incompatible with the idea of fidelity to his wife.

10 feet in height, in which were gates or other means of passing the boats. "To rectify the evils and delays of the wretched plan in use," Lombardini continues, "a second dam was constructed at a convenient distance from the first, and sluices were established connecting the space between the two dams, with the Naviglio Grande on the one hand, and the Naviglio Interno on the other. Instead of having to fill and empty an extensive tract of the canals, it was now only necessary to operate on the space between the two dams. This machine, though wanting some of the more perfect mechanical appliances of a later date, involved the true principle of the lock." Though the construction of the lock of San Maria was certainly not later in date than 1439, the idea of this class of works seems to have been entertained even earlier; for Lecchi, in his treatise on navigable canals, quotes a passage from the life of Fillippo Visconti by Pier Candido Decembrio, in which reference is made to a project entertained by that prince of connecting the Naviglio Grande at Abbiategrasso with Vigevano, on the opposite bank of the Ticino, "*colle uso delle machine che si chiamano conche*"—("by the employment of the machines called locks"). Had this plan been executed, it would have anticipated by two centuries the construction of the first canal with a double slope, as the date to which the preceding passage applies is about 1420.

The lock was described with perfect clearness in 1452 by Leon Battista Alberti, in a work entitled "De re Ædificatoria," dedicated to Pope Nicholas V., for a reference to which I am indebted to M. Lombardini.* The

* Perhaps the passages from the life of Fillippo Visconti and the work of L. B. Alberti may both be interesting to some. Here they are—

"Meditatus est et aquæ rivum per quem ab Abbiate ad Viglevanum usque sursum veheretur, aquis altiora scandentibus machinarum arte quas *conchas* appel-

year 1471 is fixed, by the date of an order of the magistrates of Milan regarding them, as that in which the two locks of Gorla and Cascina di' Pomi, on the canal Martesana, were finished.

It had long been considered desirable to place the rivers Ticino and Adda in easy and direct communication with each other; and the construction of the two locks just mentioned opened, through the canal Martesana, a line of navigation to Milan. It remained to connect this line with the Naviglio Grande, through means of the Naviglio Interno; but for many years the difficulties in the way of this were so great that no one was found willing to undertake the task. Among the Archives of the monastery of Chiaravalle,—which seems to have retained its early interest in all matters connected with the canals of the Milanese,—there exists a document under date 1496, which proves that the completion of the works of the Naviglio Interno was effected during the reign of Ludovico il Moro; and as the post of ducal engineer was held at this period by Leonardo da Vinci, there is every reason to believe that the works in question were designed and executed by him. Some of his biographers have even claimed for him the invention of the lock; but the details already given—showing the existence of such works more than seventy years before his name becomes connected with canals at all—clearly prove that this claim is unfounded. It is highly probable, however, that he improved the details; for among his papers and sketches in the Ambrosian Library of Milan there are drawings, by his own hand, of locks with double gates meeting in

lant."—"Duplices facito clausuras, secto duobus locis flumine, spatio intermedio quod navis longitudinem capiat, ut, si navis erit conscensura, cum eo applicuerit, inferior clausura occludatur, aperiatur superior: sin autem erit descensura, contra claudatur superior, aperiatur inferior. Navis eo pacto cum istac demissa parte fluenti evehetur fluvio secundo."—L. B. Alberti, chap. 12, lib. x.

an obtuse angle, just as they are made to do at the present day.

The operations for connecting the Naviglio Grande and the Martesana involved the construction of five locks on the Naviglio Interno, and the contraction of its waterway from its former breadth of 80 to about 35 feet, with the formation of revetment-walls and conveniences for navigation. The total length of the portion connecting the two great canals is 3¼ miles, with a fall of 25.2 feet, whereof 19.08 are absorbed by the locks, and 6.12 distributed along the bed. There are four small branches, whose united length is 1593.6 yards, connecting the main line with different parts of the city, on the largest of which, the Naviglio Vercellino, there is a single fall of only 1.12 feet in height. The completion of these works perfected the long-desired object of connecting Milan with the Lago Maggiore on the west, and the Lago di Como on the east. Three years after the task of Leonardo was thus successfully terminated, the Milanese passed under the dominion of France, and the native race of the dukes of Milan, great in memories both of good and evil, ceased in the person of Ludovico Sforza, carried into a lingering captivity at Loches. Louis XII., who in 1501 became master of the duchy of Milan, seems to have desired to retain Leonardo in his post as engineer; for he allotted to him part of the revenues of the canals he had so much improved. But there were other claimants upon his genius, and he remained in Milan only a very short time after the entry of Louis into that city—the gorgeous ceremonial for which he is said to have arranged and superintended.

The history of the canal Martesana contains numerous references to the destructive effects of the floods of the Adda upon the works. In 1480, part of the great Dam

was swept away, and the retaining-walls at the head were destroyed for a length of about 400 feet. Similar injuries arose from the same cause in 1566 and 1568, the upper portion of the canal being damaged by the Adda, and the lower portion by the Lambro and Sevese. In 1568 it was necessary to construct in part an entirely new channel for the canal, as the Adda had so encroached upon the old one as to destroy it; and in 1684, a very severe flood again carried away the dam, and seriously injured the other works. While the injuries thus caused were successively repaired, improvements were also executed on the alignment of the canal, which was excessively tortuous. About 1560 the supply of the canal was felt to be unequal to the demand, and the agricultural population became earnest in their call for an enlargement of the section and discharge. Not only were lands, admirably placed for irrigation, left necessarily without water, but the navigation, become of great importance since the junction with the Naviglio Grande, was constantly impeded; and to maintain a supply sufficient for it, the Administration of the canal was forced to close all the outlets in the vicinity of those spots where the deficiency was most felt. This proceeding naturally caused great discontent, especially as no provision had been made in the original grants for its becoming necessary; and it was finally decided in 1572 that an additional volume of water, equal to about 150 cubic feet per second, should be introduced into the canal. Serious difficulties, however, arose in carrying this project into execution. The upper portion of the canal was excavated in the rocky banks which bound the Adda, and its dimensions were calculated only for the smaller original supply; it would therefore be tedious and difficult to enlarge the section here. All the bridges, escapes, and other works, were in

a like predicament, and required to be enlarged along the entire length of the canal; while the necessities of the cultivators made it absolutely necessary that the canal should be closed only for a short time. The finance of the operation, too, was a puzzling question, for the government was at the time in great want of money, and the estimated expense of the works was 43,520 *lire.* Everybody, however, was in earnest in the matter, and means were found to vanquish all obstacles. The expense, which was the first consideration, was provided for by the sale in perpetuity of 33 cubic feet of the expected augmentation, which realised at once 68,775 *lire,* thus exceeding the estimated cost by 25,000 *lire.* The water realised 2084 *lire* per cubic foot—an enormous price for these times; and the whole sum due was paid in advance by the nine proprietors who had purchased the new supply. There seems, indeed, to have been a singular enthusiasm in completing the work, for the people came spontaneously to labour upon it from all parts of the district, and the utmost unanimity and energy were shown by all engaged upon it. Settala, the historian of the canal, gives the following details of the operations:—

"Three hundred master masons attacked simultaneously the rocks along the line, on a height of from 40 to 60 feet, and for a great distance in length. At the same time a multitude of labourers wrought at the excavations, throwing the earth into boats, by which it was speedily carried away and discharged into the Adda. On the whole length of the bed laid dry, the workmen were so numerous, and devoted themselves with so much energy to digging the channel, to cutting the stones, to laying the foundations, to building the masonry, &c., that they seemed like a mass of industrious bees building their

hive.* Under the dread of unfavourable weather, the works were prosecuted without any interruption, so that during the night the whole line was illuminated by the sparks struck from the hard rocks by the steel of the tools. The magistrates of Milan came in a body to visit the workshops, and to encourage the workmen, so that within the prescribed time the contract was happily terminated, and solemnly confirmed by the Governor in person."

The first result of the operation thus completed was the introduction into the canal of the full additional supply of 150 cubic feet, of which 33 were sold in perpetuity, leaving 97, however, available for general use, in securing the navigation without interference with the outlets of irrigation. The tonnage of the boats in use was doubled; and the facilities of passage now insured admitted of government deriving a considerable increase of revenue from the navigation dues.

The deficiency of the supply in the Martesana Canal had made itself especially felt in the city of Milan, for which the quantity of water was by no means sufficient. The Nirone, one of the small streams formerly devoted to the sewerage of the town, was diverted entirely to the use of the Castello, or Citadel; and the imperfect clearance, which was the consequence of this step, led to very injurious effects on the sanitary condition of the population—the frightful plague of 1576 being attributed by the old historians to the want of proper drainage, and the consequent accumulation of filth throughout the place. The enlargement of the Martesana Canal admitted of a supply of 18 cubic feet per second, being appropriated to the use of the city with excellent results on its health and cleanliness.

* *Relazione delle Naviglio Martesana*, p. 90.

It is an interesting fact to find that the principal agent in these improvements of the canal was that same President Filiodone, to whose energetic support of Soldati we have already referred in the sketch of the Naviglio Grande, and whose services to his country seem—from the terms in which his name is always mentioned—to have been of the highest order in almost all departments of the government.

In 1588 farther improvements were carried into effect on the main canal, and the whole of the Naviglio Interno was revetted anew with masonry. A Commission, which still remains in vigour, was at the same time organised for regulating the sewerage of the town, and distributing the expense thereof among those benefiting by the works. During the early part of the succeeding century, efforts were made to regulate the outlets of the Naviglio Martesana, but with results equally imperfect as on the other canals—and I see no advantage in entering into any details regarding them.

The Naviglio Martesana, like the other canals of the Milanese, suffered grievously from the accidents of war; and, by an unfortunate peculiarity, it seems to have been always by French armies that the irrigation works of this region were damaged. In the year 1658, as Bruschetti relates, the French army, under command of Francesco, duke of Modena, generalissimo of Louis XIV., crossed the Adda at Cassano. A party of miners was detached to Groppolo, and demolished at that point about 150 feet of the canal channel there formed in the rocky bank of the river. A second mine, sunk in the overhanging cliffs, threw an immense mass of earth and debris into the bed of the canal, thereby turning the water entirely into the river. The supplies of the main line, and also of the Naviglio Interno, were thus completely intercepted, and

Milan was not only deprived of water for ordinary purposes, but, as the whole of its corn-mills were stopped at the same time, it was threatened with famine. As hostilities were soon afterwards suspended here, an ingenious method was had recourse to for the supply of water to the city during the execution of the repairs of the breach. The canal was traversed by a number of siphons carrying spring waters, the property of private parties. Under the urgency of the case, all those works below the breach being broken into, the water from them passed at once into the canal bed, and, following the natural slope thereof, re-entered the city, to the great satisfaction of the inhabitants. The head of the canal was then closed by a temporary dam, and the breach, which presented the appearance of a cataract upwards of 60 feet in height, was deliberately and substantially repaired. The last catastrophe noted in the history of the canal occurred in 1711, when about 750 feet in length of the channel between Vaprio and Groppolo were carried away by the force of the water. Most unfortunately this accident occurred in the month of April, just as the demand for irrigation was commencing, and the utmost energy was necessary to complete the repairs in time to save the crop. It was considered necessary to replace the ancient earthen embankment by a vast retaining-wall of brick masonry — to strengthen the existing revetments by counterforts—and to protect the whole of the raised channel by a solid paving of concrete. The expense was estimated at 86,000 *lire;* and the same financial measures as had been employed in 1705 for the repairs of the disasters on the Naviglio Grande were again had recourse to now. All the canals were required to contribute to the expense. An extraordinary tax of 100 *lire* per *oncia*

was imposed on each permanent, and 80 *lire* on each temporary, outlet. The navigation dues, which had been increased on all the canals of the Milanese in 1705, but under a pledge that they would be reduced again in 1713, were provisionally continued at the higher rate until the debt contracted for the repairs should be liquidated. These measures, directed by the engineer Pessina, were successful, and six weeks sufficed for the completion of the necessary works. At all times the people of irrigating countries appreciate exertions like these. When the British government in India reopened the Delhi canal, thousands of people accompanied the waters as they passed slowly along their new channel—flowers were thrown into the stream—the multitude loudly expressed their joy, and welcomed with glad cheers the sight of the long-desired waters. Similarly the inhabitants of Milan collected in vast numbers along the banks of the Canal Martesana. All united in bestowing the highest praise on the Engineers and the Administration, for their energy had saved the crop of the year. It is a pleasant feature in the history of irrigation in this region, to note how, on great occasions, all parties seem cordially to have supported each other. During the remainder of the eighteenth century, there are no important historical points to record. The escapes of the canal were enlarged and improved; the slopes of the Naviglio Interno were partially remodelled, so as to make it serve more efficiently for the sanitary purposes of the city; and from time to time, up to the present day, various minor works, adding to the general efficiency, have been constructed; but I do not find in the accounts of these anything of sufficient importance to give here, and I may now pass on to the general description of the canal.

The total length of the Canal Martesana, from the head at Trezzo to Milan (including the Naviglio Interno), is very nearly 28 miles. The distribution of the slope is given below.

	Distance in miles.	Total fall in feet.	Fall in feet per mile.
Sill of the Dam at Trezzo, . . .	0.00	0.00	0.00
Bridge of Vaprio, ...	2.04	4.80	2.03
" of Groppolo, . . .	2.90	5.12	1.08
" of Cassano, ...	0.68	0.96	1.04
" of Inzago, ...	1.92	6.88	3.06
" of Fornaci, ...	2.04	4.80	2.03
" of Gorgonzola, . . .	2.28	2.46	1.06
" of Colombirolo, . . .	1.72	3.74	2.01
" of Cernusco, . . .	1.92	5.76	3.00
" of Vimodrone, . . .	2.34	6.08	2.06
" of Matalino, . . .	0.80	1.92	2.04
" of Crescenzago, . . .	1.36	2.88	2.01
" of Gorla, ...	1.24	2.43	1.09
" of Greco, ...	0.74	1.47	1.98
Fall of Cascino dei Pomi, . . .	0.32	0.19	0.06
Siphon (Tombone) of S. Marc, under the walls of Milan, ...	1.36	5.44	4.00
Totals, . .	23.66	54.93	2.03

With a slope of channel equal to 2.3 feet per mile—considerably too great for a canal of navigation and irrigation—it is difficult to understand why the second fall of Gorla should have been removed, as it was in 1553. The efficiency of the canal would have been increased by reducing instead of adding to the inclination of the bed, and the construction of more locks would have been preferable to the demolition of one of the only two existing.

The distribution of the slope of the Naviglio Interno is as follows:—

	Distance in miles.	Total fall in feet.	Fall in feet per mile.	Fall of locks in ft.
Siphon of San Marc, . . .	0.00	0.00	0.00	0.00
Lock of the Incoronata, . . .	0.03	0.15	0.5	4.16
„ of San Marco, ...	0.42	0.76	1.8	5.72
„ of the Ponte Marcellino, . .	0.09	0.76	8.4	1.60
„ of the Porta Orientale, . .	0.55	0.96	1.7	2.40
„ of Viarenna, ...	2.01	4.16	2.06	4.80
	3.10	6.79	2.1	18.68
Vercellino Branch, ...	...	18.68		
From the Bridge of the Olocati to the Piazza of the Castello, including the lock of S. Ambrogio, . .	0.74	0.0	0.0	1.12
Totals, .	3.84	25.47	2.1	19.80

For $5\frac{1}{2}$ miles, or from Trezzo to Groppolo, the bed of the canal is carried along the bank of the Adda at a height varying from 50 to 65 feet above the level of the river. Great works have been necessary in this part of the line, as the channel is sometimes cut through the solid rock, and at other times through conglomerate made impervious to the water by means of concrete. At Cassano the direction of the line changes, becoming almost perpendicular to the course of the Adda, to which hitherto it had been parallel; and on this new alignment it proceeds towards Milan, crossing the torrent Molgora, near Gorgonzola, by an aqueduct having three arches, each 64 feet in span. This work, constructed between 1460 and 1462, is reputed to be the first of the class executed in Northern Italy. Near Milan the canal receives successively the waters of the rivers Lambro and Sevese, for the escape of which outlets are provided on the left bank. As both these streams carry much earthy matter, their

influence on the bed of the canal is very mischievous. The principal districts intersected by the canal are those of Concesa, Vaprio, Fornaci, Groppolo, Gorgonzola, Colombirola, Crescenzago, and Milan.

The most important works along the line, in addition to the dam across the Adda at Trezzo, and the aqueduct just mentioned, are—1st, The great weir at Concesa, a massive structure of stone masonry attached to the dam, 879 feet in length. At its lower extremity are 3 regulating escapes, having 22 sluices of the ordinary construction and dimensions. 2d, The escapes of Vaprio, two in number, and having together 7 sluices. 3d, The aqueduct of Gorgonzola, mentioned before. 4th, The escape of Fagone at Vimodrone, consisting of a single large sluice. 5th, The escape of the river Lambro, having 19 sluices of the usual size, and a weir 90 feet in length. 6th, The lock of Cascina dei Pomi, 146.87 feet long, 19.44 broad, with a fall of 5.76 feet. A mill is established on the adjoining escape-line, maintained at the expense of the renter. 7th, Escape of the river Sevese, being a weir 36 feet in length. 8th, At Milan the great escape of the Redefosso, consisting of 12 sluices, and a weir 88½ feet in length. The whole of the escapes are of brick masonry, solidly and substantially built. 9th, 13 bridges and aqueducts.

The works designed to protect the canal from the attacks of the Adda are concentrated within the first six miles of its course, while it skirts the river bank. These works are, 1st, Between Concesa and Vaprio, 2033 yards of revetment-wall, partly of masonry, partly of boulders. 2d, Between Vaprio and Groppolo, the dike of the Cappellata, 2854 feet in length, of massive masonry, protected at bottom by piles and masses of rock. 3d, The dike, or rather spur, of Fava, 1214 feet long, constructed of flat

stones without cement, and protected by piles, &c., like the preceding. 4th, The great spur of Morone, 1935 feet in length, which, being established at a point peculiarly liable to attack, has been of the utmost use, and though often damaged by floods, is always maintained with great care. Smaller spurs and other protective works are scattered along the entire six miles, but it is unnecessary to note them in detail, as they are in no way remarkable.

The banks of the canal are protected for a length of nearly 28 miles by revetment-walls of masonry, and the whole of the Naviglio Interno, being 7½ miles more, is similarly secured against injury by the current.

The necessity for watching carefully the state of the water in the Adda has led to the establishment of a number of hydrometers, of which the principal is at Concesa. By that the regulation of the supply is controlled, and on the occurrence of floods the height of the water upon it indicates the number of sluices which must be opened to prevent accidents. Other hydrometers are established at the various escapes, of which the most important is that near the siphon or aqueduct of San Marc, by which the supply of the Naviglio Interno is regulated. As the lower portions of many of the houses in Milan are under the ordinary surface-level of the canal, considerable delicacy is necessary in managing the supply so as to avoid inundation ; and the necessity for this is further increased by the vicinity of the Lambro and Sevese, both of which are subject to rapid and considerable floods. The usual form of these hydrometers is a slab of granite 5 feet high, 2 feet wide, and about 8 inches thick, in which is imbedded a marble scale graduated in local measures.

On the Naviglio Interno there are the following

works:—1st, Seventeen bridges of stone or brick masonry, having each, with a solitary exception, a single arch with a span equal to the breadth of the canal, which varies from 30 to 34 feet. The exceptional bridge has two arches. 2d, Three station-houses and store-rooms, with land attached for receiving the earth excavated from the canal during clearances. 3d, Five locks, whose lengths vary from 103 to 120 feet, and breadths from 18.84 to 22.9 feet. 4th, Three escapes, each having 2 sluices. These escapes are the oldest masonry works on the canal, and that near the church of St Appolinarius, which is the head of the Vettabia, dates from 1169, so that it is now nearly seven hundred years old.

The permanent local establishment for the canal Martesana consists of 8 guardians, for whom quarters are provided along the canal banks. Each guardian has charge of a district varying from 2 to 6 miles in length, according to the importance of the works. The chief guardians are at Concesa, the head, and San Marc, the termination of the main line. I may speak of the qualifications of these officers from personal experience, and I was equally pleased with the perfect knowledge of the works under their charge which they displayed, and the courtesy with which they accompanied me during my inspection of them. The guardian at Concesa, whose name, I am sorry to say, I have forgotten, was particularly intelligent and obliging. These functionaries receive salaries varying from £20 to £25 per annum, with free quarters, and the use of the ground attached to the station-houses.

The annual repairs of the canal are effected, as in other cases, in April and September. A notification is issued from the office of the Director of Public Works in March, fixing the dates between which the canal will be

stopped, and warning the owners of all boats to avoid entering the channel after the day specified for closing. All works are then repaired, the bed cleared of deposits and aquatic plants, which are very troublesome here, as elsewhere in the Milanese. The September clearance is generally limited to the removal of the deposits of the Lambro and Sevese, and a second cutting of the plants in the bed. There is a kind of regulating bridge near Concesa, one arch of which is closed by gates, while the other has sluices fitted to it. By closing the gates and sluices, and opening the escape adjoining, the canal is laid dry with facility. When it is necessary to close the canal at the head, a temporary dam is employed about 50 feet in breadth and 8 feet in height. I saw no reason why this system of temporary dams, always troublesome and imperfect, should not have been replaced on all the canals by permanent regulating bridges with gates, which would give a far better command over the supply than now exists. The first expense would, of course, be greater, but the plan would be more efficient, and, in the end, more economical than that now adopted. But the "wisdom of our ancestors" has its effect in Italy as elsewhere; so the old system, in all its cumbrousness, continues to be employed. The clearance of the Naviglio Interno is effected by a species of dredging-machine drawn by horses, and by an extensive use of "flushing"—a powerful stream being driven through the channel, and through all the subterranean sewers connected with it, so that the whole of the deposits in them are swept into the main discharge-line of the Vettabia, to be employed there in producing that wonderful fertility to which I have already referred.

The number of irrigation outlets on the canal Martesana is 85, of which 75 are on the left, and 10 on the right bank. Their discharges vary greatly, ranging from

one-fourth of a cubic foot to 40½ cubic feet per second. In looking over the tabular statement of these outlets given by Bruschetti ("*Irrigazione*," p. 461), it is curious to remark the indefinite manner in which the discharges of some are intimated. The only limitation is made in such terms as—"for the irrigation of a meadow of 40 *pertiche* in summer-time, to be opened once a-week for 24 hours;" "for 20 hours once a-week;" "for 5 days a-week,"—and so on, in equally vague terms, there being no limit put to the dimensions of the outlet. The majority, however, are for grants in perpetuity for summer and winter, or for summer only, and a considerable number are bound to return the surplus waters into the canal. The general average discharge of the outlets is from 7 to 9 cubic feet per second, and no single outlet is permitted to have a higher volume than the latter quantity.

The quantity of water employed in irrigation on the line of the Martesana canal (excluding at present the Naviglio Interno) amounts in summer to 738 cubic feet per second, as measured by the actual discharges of the outlets. The total volume of the canal, measured at Concesa during a period of average supply, amounts to 981 cubic feet per second, whereof 138 cubic feet are allotted to the Naviglio Interno, and the remainder—843 cubic feet—to the canal Martesana. Hence the wastage from evaporation, filtration, and illegal abstraction of water, is 105 cubic feet per second—equal to 3.75 cubic feet per second per mile of length, which approximates to the same datum on the Naviglio Grande.

The outlets granted in perpetuity for winter irrigation dispose of 457½ cubic feet per second. But there are usually about 225 cubic feet more, which are granted from year to year; and hence the total winter supply amounts to 682½ cubic feet per second.

On the Naviglio Interno, from the siphon of San Marc to the lock of Santa Maria, there are 30 outlets, of which 24 are on the left, and 6 on the right bank. The volumes of these range from half a cubic foot to 50 cubic feet per second, and the mean of the whole is from $4\frac{1}{2}$ to 6 cubic feet. The united discharge of the entire number of outlets exceeds 200 cubic feet, while the actual discharge of the canal is only 138 cubic feet—an apparent discrepancy which is easily explained, by the fact that the outlets in the upper part of the canal return all their surplus waters into it again at lower levels, thus affording a supply to the channels there. The united volume of the Martesana and Naviglio Interno employed in irrigation is, therefore, 876 cubic feet per second.

The area irrigated by the above quantity of water amounts in summer to 58,900 acres, being 67.2 acres for each cubic foot of continued discharge. The winter irrigation extends over 1150 acres, giving 1.3 acres for each cubic foot.

The following official table gives the minimum rates at which water is sold on the Martesana:—

TABLE of PRICES of WATER, on the CANAL MARTESANA, per Cubic Foot per Second.

			£	s.	d.
From Cassano to Colombirolo.	Continued irrigation.	Purchase, ...	£314	0	0
		Long lease, ...	13	6	8
		Annual lease, . .	12	11	4
	Summer irrigation.	Purchase, ...	280	6	8
		Long lease, ...	12	1	4
		Annual lease, . .	11	4	6
From Colombirolo to Milan.	Continued irrigation.	Purchase, ...	326	4	8
		Long lease, ...	13	17	4
		Annual lease, . .	13	1	0
	Summer irrigation.	Purchase, ...	294	16	8
		Long lease, ...	12	13	9
		Annual lease, . .	11	6	0
Average price of water, for winter irrigation, per cubic foot per second, . .			£1	17	6

From these details it appears that the cost of summer irrigation per acre for water alone ranges from about 4s. for continued, to 3s. 6d. for summer irrigation—rates as low as on the Naviglio Grande. For the *marcite* or winter irrigation, the rate per acre for water rises to about £1, 8s. The selling price of a cubic foot of water ranges from 23 years' annual rent for continued, to 25 for summer irrigation. The preceding table gives the minimum prices of water, but the current prices differ very little from these, as, from some data kindly furnished by Count Lorenzo Taverna, relative to the Cavo Taverna, a modern work, I find that the sum paid for 15 cubic feet of water amounted to £4823, 15s., being on an average very nearly £322 per cubic foot per second.

The annual cost of repairs and maintenance of the Martesana canal amounts to nearly £1200, including the salaries of the local establishment. In this sum is comprised half the expense of maintaining the Naviglio Interno, the other half being defrayed by the proprietors of the land and houses benefiting by the canal, under rules administered by a municipal body, elected by themselves. What the precise amount of this is I do not know, but it is very small.

As on the other government canals, so on the canal Martesana, the gratuitous alienations, or the sale in perpetuity of the waters, have reduced the actual income to a very trifling sum. From all sources, the annual revenue derived from it does not exceed from £1400 to £1500, thus being little more than sufficient to cover the current expenses.

In the upper portion of the canal, the water furnishes motive power to about 60 mills of various kinds, and within the city there are 32 more supplied from the Naviglio Interno. Many of these wheels are of the same

rude construction as is at this moment employed by the natives of India, having merely flat horizontal spokes on which the water falls obliquely. The waste is excessive, and one wonders to find, in such a region, mechanical resources so far in arrear.

About 6 miles north of the head of the canal Martesana at Trezzo, a small line, under the name of the Naviglio di Paderno, has been constructed for navigation only. Such a work does not, therefore, properly belong to my subject; but to complete this view of the canals on the right bank of the Adda, I may say a few words regarding it.

At Paderno the Adda is a perfect cataract, having, in the space of a mile and a half, a fall of fully 90 feet, or 60 feet per mile! The rapids thus formed opposed an insurmountable obstacle to navigation between the Lake of Como and Milan, and hence efforts were early made to turn them by an artificial channel, duly regulated by locks. At the beginning of the sixteenth century, or between 1516–18, a project was submitted by the engineer Benedetto Missaglia, for a canal excavated through the solid rock bounding the rapids; but the troubles of the time interfered with the execution of the project, and it was not till the end of that century that the works were actually commenced. The designs for the work were prepared by Giuseppe Meda, an architect and painter of Milan, whose conceptions were as gigantic as their execution proved disastrous. He proposed disposing of a fall amounting to 77.84 feet by two locks only, one having a height of 19.5, the other of 58.39 feet! The authorities were naturally startled by a scheme possessing features so remarkable, but Meda himself having taken the contract for its completion, they sanctioned its commencement in 1591. For nearly eight years the works were carried on under all sorts of difficulties—want of money—insubordi-

nation among the workmen rising to such a height that Meda had to carry arms for his own defence, and to call constantly for the military force to support him—quarrels among the engineers—discontent on the part of the magistrates—and finally, in 1599, the failure of the contract, and the imprisonment of the unfortunate projector himself, on the charge of misconduct and peculation. Sick and disgusted when put in prison, Meda was acquitted of the charge of fraud, and released only to die, as, in the month of August 1599, his unlucky career was finally closed. The works were continued, though on modified plans, but it was not till 1777, a hundred and eighty-six years after their commencement, that they were finally completed and opened for public use. The canal at present existing has a length of 1.6 miles, and a total fall of 90.69 feet, of which 3.9 feet form the slope of the channel, and 86.79 feet are absorbed by 6 locks, ranging from 10.72 to 20 feet in height. The largest of the locks preserves the memory of the ill-fated projector of the canal in its name of "The Grand Lock of Meda." The dam at the mouth has three escapes, and in the bank which separates the canal from the river there are three other escapes, with 28 sluices, by which the supply is regulated. The breadth of the canal is from 36 to 39 feet, and its discharge about 90 cubic feet per second. The works, and especially the bottom, require much repair; so that, for its length, its annual cost of maintenance is considerable, being nearly £240 in all, or £160 per mile.

The Ticino, on the west, and the Adda, on the east, limit the region of the first-class canals of Lombardy. On crossing the latter river, though we still find extensive irrigation and numerous canals, the former is far less perfect, and the latter are far

inferior in magnitude and interest to what we have found in the Milanese. I do not think, therefore, that it would be of interest or value to enter into the same extent of detail regarding the canals east of the Adda, as I have felt justified in doing regarding those to the westward; and I will, accordingly, restrict myself to a summary of those points which will suffice to complete our view of the extent of the irrigation system of Lombardy.

Before doing so, however, it will be interesting to present a general summary of the extent to which irrigation has been carried in the Milanese. The following details show the total areas of irrigation from the different rivers :—

	Area in acres. Summer.	Area in acres. Winter.
From the Ticino, ...	113,390	2237
„ the Olona, Lambro, &c., . .	20,181	400
„ the Adda, ...	241,400	3900
„ Springs or Fontanili, . . .	96,000	1300
Totals, . . .	470,971	7837

The cultivated or culturable area of the irrigable zone included between the Ticino and the Adda may be estimated approximately at 520,000 acres. As the total area of irrigation within this tract amounts to 471,000 acres, it appears that the rich province of the Milanese is irrigated to the extent of not less than nine-tenths of its arable surface—a proportion to which there is not, so far as I know, any other comparable case in the world.

No. XI.—Historical and Descriptive Data connected with the Canals of the Adda.

	Supplying river.	Date of construction.	Position of head-works.	Works.				Length of channel in miles.
				Bridges.	Aqueducts, dams, &c.	Falls.	Irrigation outlets.	
1. Canal Muzza, . .	Adda	1220	Cassano	14	25		75	43½
2. Canal Martesana, and		1457	Trezzo	13	16	1	85	
Naviglio Interno of	Do.							27½
Milan, . . .		1440		17	6	5	30	
Totals, . .	...	...	...	44	47	6	190	71

No. XII.—Agricultural and Financial Data connected with the Canals of the Adda.

	Volume in cubic feet per second.	Area of irrigation (summer) in acres.	Price of water.		Annual expenditure in pounds sterling.	Annual income in pounds sterling.	Irrigation in acres per cubic foot per second.	Indirect returns.
			By fixed opening per cubic foot per second.	By area per acre.				
1. Canal Muzza, . .	2652	182,500	16/6	/3	794	1476	83.9	104,500
2. Canal Martesana and Naviglio Interno of Milan, . . .	981	58,900	£11 to £13	4/ to 3/6	1200	1400	67.2	35,340
Totals, . .	3633	241,400	..	..	1994	2876	75.55	139,840

SECTION V.

CANALS OF THE ADDA (LEFT BANK), THE BREMBO, THE SERIO, AND THE OGLIO (RIGHT BANK).

I have grouped together the canals from the four rivers above noted, because, with the waters supplied by them, the tract included between the Adda and the Oglio, and composed of the provinces of Bergamo, Crema, and Cremona, is irrigated.

The canals on the left bank of the Adda are three in number, which, in the order of their succession, are given below.

No. I.—CANALS of the ADDA (Left Bank).

Names of Canals.	Position of head.	Volume in cubic feet per second.	Area of Irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts irrigated.
1. Vajlata, . .	Canonica	120	11,250	93.7	Bergamo
2. Ritorto, . .	Cassano	270	24,500	90.7	and
3. Rivoltana, .	Do.	24	2,250	93.7	Crema.
Totals, .		414	38,000	92.7	

The canals from the Brembo are five in number, of which four are established on the left, and one on the right bank. The details of interest connected with these are as follow:—

No. II.—CANALS of the BREMBO.

Names of Canals.	Position of head.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts irrigated.
Right Bank.					
1. Seriola di Filago,	Ponte S. Pietro	32	3000	93.7	Ponale, Medone, Filago, in Prov. of Bergamo.
Left Bank.					
2. Seriola Brambilla,	Treviolo	54	4875	90.2	Bergamo, and Upper Crema.
3. „ Visconti,		72	6500	90.2	
4. „ Trevigliese,		108	9750	90.2	
5. „ Melzi, .		32	3250	101.5	
Totals, .		298	27,425	91.45	

From the river Serio there are derived 14 canals, of which 6 have their heads established on the right, and 8 on the left bank. Their leading details are given in the subjoined Table:—

No. III.

No. III.—CANALS of the SERIO.

Names of Canals.	Position of head.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts irrigated.
Right Bank.					
1. Roggia Serio, . .	Albino.	72	6,000	83.3	Bergamo, between the Brembo and the Serio.
2. „ Morlana, .	...	61¼	5,100	81.6	
3. „ Guidana, .	Alzano.	18	1,500	83.3	
4. „ Vescovada, .	Ranica.	12	1,050	87.5	
5. „ Fonte-perduto,	Gorla.	16½	1,350	81.8	
6. „ Vecchia, .	Seriate.	15	1,200	80.0	
Left Bank.					
7. Roggia Borgogna, .	Villa-serio.	63	5,250	83.3	Bergamo, between the Serio and the Oglio.
8. „ Brusaporta,	Predengo.	36	3,000	83.3	
9. „ Cattanea, .	Seriate.	27	2,250	83.3	
10. „ Babbiona, . } 11. „ Malcorrente, } 12. „ Menasciutta, } 13. „ Archetta, . } 14. „ Renata, . }	From Ricengo to Crema.	180	17,500	97.2	Lower Crema and Western Cremona.
Totals, . .		501	44,200	88.2	

The canals from the Serio are of uncertain discharge in the summer-time, in consequence of the want of perpetual snow in the Orobian Mountains, among which the river has its source. A curious trace of this uncertainty is found in the names given to two of the canals in the preceding table, the Malcorrente and the Menasciutta, the "ill flowing" and the "half dry." The former occupies the bed of what is sometimes called the *Serio Morto*, a large drainage-channel which collects the surplus waters of the provinces of Bergamo and Crema, carrying them into the Adda, near the fortress of Pizzighettone.

In the province of Bergamo, the two districts of Fiescorre and Sarnico are irrigated from the small stream

Cherio, the escape-line of the Lago Endine. The extent of irrigation is about 2000 acres.

From the right bank of the Oglio there are derived several canals of considerable dimensions and great antiquity. The principal of these is the Naviglio Civico of Cremona, constructed in 1372, and having its head near Calcio. Its ordinary discharge, as measured by Lombardini in 1841, amounted to 648 cubic feet per second; but when water is abundant in the river, this quantity is increased to nearly 900 cubic feet. Below Fontanella the canal divides into two branches: that on the right, after uniting with the Naviglietto di Barbata, supplied by drainage and surplus waters, is called the Naviglio Vecchio, or Old Canal; while the left branch is called the Naviglio Nuovo, or New Canal. After flowing separately for about 7½ miles, the two branches are reunited, and the stream is then termed the *Coda del Naviglio*, or, *Tail of the Canal.* On reaching the city of Cremona, part of the water is turned into the ditch, and part flows through the town. The canals on the left bank of the river for the irrigation of the province of Brescia have diminished the supply of the Naviglio Civico; but it is proposed to connect various drainage-lines with the latter, and so increase its available volume.

The Naviglio Pallavicino, so called from the family by whom it was constructed, and to whom it now belongs, is also an old and important line. Its head is established on the right bank of the Oglio near Pumenengo, and it joins the Roggia di Calcio and the Naviglio Nuovo, near Torre Palavicina, the united volume of the three channels being about 650 cubic feet per second. As an illustration of the extent to which irrigation is developed from these canals, I find it stated by M. Lombardini, that in a space of about 500 feet in length of the road between

Cremona and Bergamo, near Genivolta, there are 13 aqueducts, or an aqueduct at every 40 feet! The spot is termed, from this circumstance, *I tredici Ponti*, the Thirteen Bridges.

I give below some of the details of interest connected with the canals on the right of the Oglio, by which the irrigation of Lower Bergamo and part of Cremona is effected.

No. IV.—CANALS of the OGLIO (Right Bank).

Names of Canals.	Position of head.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts irrigated.
1. Roggia Sale, .	Palozzola	36	3,500	97.2	Bergamo, between the Serio and Oglio.
2. „ Donna, .	Cividate	40¼	4,000	98.7	
3. Naviglio Civico of Cremona, . } 4. Roggio Calcio, .	Calcio	648	67,500	104.1	Upper and Central Cremonese.
5. Naviglio Vecchio Pallavicino, . } 6. Naviglio Nuovo Pallavicino, .	Pumenengo Torre Pallavicina	648	67,500	104.1	
Totals, .		1372¼	142,500	101.3	

From the preceding details it appears that, in the zone between the Adda and the Oglio, irrigation is developed as below:—

	Area in acres.
From the Adda, ...	38,000
„ Brembo, ...	27,425
„ Cherio, ...	2,000
„ Serio, ...	44,200
„ Oglio, ...	142,500
„ Springs and small streams, . .	37,654
Total, . .	291,779

The culturable area of this tract of country may be estimated approximately at very nearly 1,400,000 acres, so that it is irrigated to the extent of about one-fifth of this area. The water is employed chiefly in the irrigation of meadows, Indian corn, and flax. In Crema and Cremona rice cultivation is practised, but to a far less extent than westward of the Adda. The price of water is considerably lower in the provinces of Bergamo, Crema, and Cremona, than in the Milanese. Its selling price averages about £250 per cubic foot per second, and the annual rent for the same quantity varies from £10 to £12. There is comparatively little *marcite* or winter-meadow cultivation; and such examples of it as I saw were decidedly inferior to that in the zone between the Adda and the Ticino, both in the system of disposing the soil and distributing the water. As all the canals included between the Adda and the Oglio are municipal or private property, I could not obtain any data regarding their current expenses, revenues, or original cost. Supposing, however, that in this part of the country irrigated land returns only ten shillings per acre more in rent than land unirrigated—and this is, I believe, a moderate estimate—we have upwards of £140,000 per annum added to the agricultural rental of the three provinces, from the employment of the waters of the five rivers by which they are intersected.

SECTION VI.

CANALS OF THE OGLIO (LEFT BANK), MELLA, CLISIO, MINCIO; WITH SOME DETAILS OF THE IRRIGATION FROM THE SMALL STREAMS BETWEEN THE MINCIO AND THE ADIGE.

Twenty years after the inhabitants of Cremona had constructed the Naviglio Civico, the province of Brescia commenced to avail itself of the rivers traversing it for purposes of irrigation. The first canal constructed was the Cavo Fusio, which, having its head immediately below the point at which the Oglio issues from the Lago d'Iseo, was carried along the high bank skirting the river to Palazzolo, whence it was continued to Rovata at nearly the level of the country. It was originally opened in 1347 by the Count Oldofredo d'Iseo; but during the progress of the wars of the sixteenth century, the proprietary right to it was held by many different parties. At present it belongs to the inhabitants of Rovata, and is said to be a source of considerable revenue to them. It was considered of sufficient importance to be the object of a special treaty between the Empress Maria-Theresa and the Venetian Republic in 1754, when the Oglio divided the territories of Austria and Venice. The canal is navigable for small boats from its head to Rovata, and forms a connecting link between this part of the province of Brescia and the Lago d'Iseo. Its discharge is about 240 cubic feet per second, and its breadth from 25 to 30 feet. There are nine other canals on the left of the Oglio, of which I give some details below :—

No. V.—CANALS of the OGLIO (Left Bank).

Names of Canals.	Position of head.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts Irrigated.
1. Canal Fusio, .	Sarnico	240	21,750	90.6	Western and Upper Brescia
2. ... Chiari, .	Palazzolo	360	32,500	90.2	
3. ... Castrina, .	...	108	9,750	90.2	
4. ... Trenzana, .	...	126	11,500	91.2	
5. ... Bajona, .	...	198	18,000	90.9	
6. ... Rudiana, .	Pontollio	126	11,500	91.2	
7. ... Castellana,	...	102	9,250	90.6	
8. ... Vescovado,	Urago	60	5,375	89.5	
9. ... Rovati, .	...	127½	10,582	83.0	
10. ... Orci-Novi, .	...	75	6,225	83.0	
Totals,	...	1522½	136,432	89.04	

The lengths of these canals are very variable, ranging from 2 to 20 miles, the total length being about 80 miles.

There are six canals supplied by the river Mella, of which one is on the right, and five on the left bank. The following table exhibits their details :—

No. VI.

No. VI.—CANALS of the MELLA.

Names of Canals.	Position of heads.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation per cubic foot per second.	Districts irrigated.
Right Bank.					
1. Seriola Gambaresca,	Morico	90	7500	83.3	
Left Bank.					
2. Canale Celato, .	Concesio	46½	3900	83.8	Central Brescia
3. Fiume Bova, .	San Bartolomeo	90	7500	83.3	
4. „ Grande,	Do.	82½	6900	83.6	
5. Seriola Capriana,	Fenili	72	6000	83.3	
6. „ Morica, .	Capriano	48	4500	93.7	
Totals,	...	429	36,300	85.1	

The two canals in this table, named the Fiumi Bova and Grande, are among the most ancient in Lombardy, having been originally constructed between 1298 and 1308 by the Bishop Berardo Maggi, then Signor of Brescia. They were thus preceded only by the Naviglio Grande and the Muzza.

The construction of the first and the largest of the canals of the Clisio is due to the same Bishop Maggi. This line, under the name of "the Naviglio," has its head at Gavardo on the Clisio, from whence it flows past the city of Brescia, and through the centre of the province for about 45 miles. It has a volume amounting to 504 cubic feet per second, which is distributed for agricultural purposes through 76 outlets. After seeing this work, however, I cannot say I found anything of particular interest connected with it. In addition to the

Naviglio, the Clisio supplies three other canals, of which I give some details below :—

No. VII.—CANALS of the CLISIO.

Names of Canals.	Position of heads.	Volume in cubic feet per second.	Area of irrigation in acres.	Irrigation in acres per cubic foot per second.	Districts irrigated.
Right Bank.					
1. The Naviglio, .	Gavardo	504	45,500	90.2	Central Brescia
Left Bank.					
2. Seriola Lonata .	Cantrina	231	20,800	90.1	Eastern Brescia
3. „ Calcinato-Montechiaro,	Ponte S. Marco	57	5,200	91.2	Mantua
4. „ d'Aquanegra,	Asola	36	3,250	90.2	Mantua
Totals,	...	828	74,750	90.4	

In addition to the water derived from the Oglio, the Mella, and the Clisio, the province of Brescia is rich in springs. It is estimated that about 180 cubic feet per second are derived from these, and employed in irrigating about 16,560 acres.

The Mincio supplies only one large canal for the irrigation of the province of Mantua. It is called the Fossa di Pozzolo, from the place at which its head-works are established. It is a canal of the fourteenth century, and its history presents the general features common to all those ancient lines. In 1630 it suffered much from the accidents of war, nearly all its principal works being then destroyed, and its waters left to spread over the country, and to form extensive and mischievous swamps. The proprietors of the lands through which it passed raised among themselves a sum of nearly £10,000

for the repair of the injuries sustained. In 1637 the number of outlets was 14, and their united discharge was then about 300 cubic feet per second. Now, the supply for irrigation averages 510 cubic feet per second, and is obtained from the Mincio by means of a strong dam of stone-work, revetted with slabs of marble, and having a length of 1378 feet. There are five escapes having 16 sluices, formed in the body of the dam for the passage of floods; and at the head of the canal there is a regulator with eight sluices, each $2\frac{3}{4}$ feet in breadth, and arranged like similar works in the Milanese. The flanks of the regulator and the banks of the canal below it are protected for a considerable distance by revetments of masonry. The mean breadth of the canal varies from 30 to 40 feet, and the number of branches is so considerable that the whole of the supply is absorbed. The area of irrigation of the Fossa di Pozzolo is 20,500 acres, giving about 40.2 acres for each cubic foot per second, a result which, being less than half what we have found to prevail in Bergamo, Cremona, and Brescia, may be explained by the fact that a very large proportion of the irrigation in Mantua is for rice cultivation, which requires at least double the quantity of water necessary for ordinary meadows.

In addition to the Fossa di Pozzolo, the Mincio supplies five other small channels, relative to which, however, I am not in possession of any detailed information. They are called—1. Cavo di Massinitona; 2. Cavo Bertone; 3. Cavo del' Isola; 4. Cavo dell' Isoletta; 5. Naviglio di Goito. These irrigate a few thousand acres in addition to the quantity above stated.

The remaining irrigation in the district between the Clisio and the Adige, comprising parts of the provinces of Mantua and Verona, is effected solely by the waters of the small rivers, which occur abundantly therein. I can-

not attempt to estimate it exactly, but the entire amount does not probably exceed from 8000 to 10,000 acres. The vast marshes, however, which cover so large a proportion of the surface of this tract, limit greatly the application of irrigation. Extensive drainage-works now exist, and still more extensive ones are projected for the improvement of this region; but till these are all in full operation, and have produced their anticipated effects in restoring the great wastes to cultivation, the extent of irrigation must continue to be very restricted. From the various rivers, the Caldone, the Osone, the Tartaro, the Tione, and many more, upwards of 70 channels of distribution have been drawn ; and in the application of the water to rice-grounds, which have existed here for several centuries, these channels are of great value to the community. As regards other irrigated products, the results are exceedingly uncertain; for in seasons when rain falls rather more abundantly than usual, the deficiency of drainage leads almost invariably to the ruin of the crop.

In making a summary of the whole of the preceding details, we find that in the zone included between the rivers Oglio and Adige, including the provinces of Brescia, Mantua, and part of Verona, we have irrigation developed to the following extent :—

	Area of irrigation in acres.
From the Oglio (*left bank*),	136,432
„ the Mella,	36,300
„ the Clisio,	74,750
„ the Mincio,	20,500
„ smaller streams,	10,000
„ springs,	20,560
Total acres,	298,542

According to the table of statistics attached to the great map of the Lombardo-Venetian provinces, the cul-

tivated or culturable area of this zone is stated to be 1,953,972 acres. Hence it is irrigated to the extent of about one-seventh of this area, or about one-tenth of its total superficies, including sterile as well as productive land. The price of water is much the same as between the Adda and the Oglio, and the gross addition to the rental of the land due to irrigation may be estimated at about £150,000 per annum.

SECTION LAST.

GENERAL SUMMARY OF THE IRRIGATION SYSTEM OF LOMBARDY.

In finishing our survey of the irrigation system of Lombardy, it may be useful to present a general view of its most prominent features. I have already mentioned that the total area of the provinces in which irrigation is more or less perfectly developed, may be approximately estimated at 6½ millions of acres. The entire irrigated area of Lombardy is exhibited below :—

	Area of Irrigation.	
	Summer.	Winter.
1. Zone between the Ticino and the Adda, .	470,971	7,837
2. Do. between the Adda and the Oglio, . .	291,779	2,500
3. Do. between the Oglio and the Adige, . .	298,542	2,500
	1,061,292	12,837

Viewing the plain as a whole, it is irrigated to the

extent of about 1-6th of its total, and about 1-5th of its productive area. There is a progressive decrease in the ratio of irrigation to area, as we proceed from west to east. Between the Ticino and the Adda, irrigation is applied over nearly 9-10ths of the surface; between the Adda and Oglio, over about 2-10ths; and between the Oglio and the Adige, over not more than 1-7th or 1-8th. In the Milanese, Lombard authorities estimate the extent of rice cultivation at about one-half the total irrigated area, the remaining half being occupied either by permanent or rotation meadows, Indian corn, and flax. Between the Adda and the Oglio, rice is comparatively rare; but in the low lands of Mantua and Verona, it occupies 2-3rds of the productive area.

The great government canals have a total length of 133 miles; but dependent upon these main lines there are 353 branches, some of which are of very large dimensions; and if an average length of 10 miles be assumed for each, we have a network of distribution channels of the first class equal to 3530 miles in aggregate length. To approximate even to the length of the minute arteries of the system is quite impossible. When the great map of the country is examined, it seems as though scarce an acre of the entire surface of the Milanese were without several intersecting channels. To the eastward of the Adda, the length of the canals is less; but still it does not fall under from 700 to 800 miles. It is not, I think, therefore, an exaggeration to say that the entire length of canals of irrigation in Lombardy, including the great lines and their first-class branches, exceeds 4500 miles.

Though the financial results of this remarkable development of irrigation have been of small direct benefit to the state, or to those individuals who have concerned themselves in canal works as commercial speculations, their

indirect benefit, as indicated by the difference of rent between irrigated and unirrigated land, has been most marked. At a very moderate estimate, the increased returns from the land throughout the Milanese alone may be estimated at £270,000, and in the other irrigated provinces at about £290,000 per annum; representing a capital value of fully fourteen millions sterling due to the employment of water in the agriculture of this fertile region. This statement is, however, so to speak, but one side of the account; it shows us what has been realised, but it does not show us what has been spent. The remote epochs at which the great canals, and a very large proportion of the branches, were constructed—the admixture of works for navigation with those required purely for irrigation—and the difficulty of obtaining access to the records of private undertakings, oppose almost insuperable obstacles to the formation of a trustworthy estimate of the amount of capital which has been expended in producing throughout Lombardy that astonishing system which we have been describing. It is not merely the cost of canal works which forms the chief item in the expenditure; in addition to this, vast sums have been expended in adapting the ground for the use of water—high places have been lowered—low places have been raised—the entire surface of the country has been plastic, as it were, in the hands of the irrigators—and the amount of capital thus invested in the soil has been very great. Signor Cattaneo ("*Instituzioni Agrarie dell' Alta Italia,*" &c., p. 44-51) estimates the cost of introducing, over an area of 500,000 acres, a system of irrigation on a grand scale like that of the Milanese, with its great trunk-lines of canal, its first-class branches, its modifications of surface, its immense establishments for farming purposes, and its internal works for the distribution and application of the

water, at forty millions sterling, or £80 per acre! From an analysis of the items of this estimate, I think it is in excess of the truth; but making every possible deduction, even to the extent of one-half, it would still appear that, for the irrigation of the million acres, which, in round numbers, represents the total irrigated area of Lombardy, there must have been expended a capital of not less than the sum above stated. This expenditure has been spread over seven hundred years; it has converted a *maremma* into a garden; and though, when presented in the form of a bare money account, its results are not great, yet its real effects are to be traced, and its true history read, on the face of the land, and in the material condition of its two and a half millions of inhabitants.

The river system of Lombardy is drawn upon for irrigation to the following extent:—

	Cubic feet per second.
From the Ticino,	2,260
... Adda,	4,047
... Brembo,	298
... Serio,	501
... Oglio,	2,895
... Mella,	429
... Clisio,	828
... Mincio,	720
... Minor Streams,	600
... Springs,	2,540
Total,	15,118

I have before mentioned that the total average discharge of the various rivers is nearly 30,000 cubic feet per second, so that one-half of this is utilised by being made available for the three objects of irrigation in Agriculture, navigation in Commerce, and supplying motive force in Industry. The general average area irrigated by each cubic foot of water, throughout Lombardy, amounts to 70.2 acres, and the general rate of cost per acre for water only is very nearly 3s. 6d.

Throughout the entire valley of the Po, including Piedmont and Lombardy, the extent of irrigation amounts to 1,547,905; or, in round numbers, 1,600,000 acres, being about one-sixth of its total area. The mass of water utilised is nearly 24,000 cubic feet per second, the value of which, in capital, at £250 per cubic foot per second amounts to four millions sterling, and the increased rental due to its employment is, at a very moderate estimate, £830,000 per annum. I need not dwell longer on such details. A few of them, even though they are only approximate, are still interesting, as giving some distinct ideas of the extent and the value of the system. To minds accustomed to the statistics of England, they may not seem imposing; but regarded in reference to the comparatively limited districts to which they apply, they are, in truth, large and important.

I have now completed the first great section of my work, in giving the historical and descriptive details of the canals of irrigation in Piedmont and Lombardy. The second—which will include the systems of Measurement, Distribution, and Practical Application of the waters, with the Legislation of Irrigation within the same kingdoms—remains to be completed; and to these branches of the subject I propose to devote the succeeding portion of this work.

APPENDICES.

APPENDIX A.

LIST OF ITALIAN AUTHORS ON THE HISTORY, PRACTICE, AND LEGISLATION OF IRRIGATION IN NORTHERN ITALY.*

[Referred to at p. 15, Chapter 1, Part I.]

SECTION I. — ON THE CONSTRUCTION AND ARRANGEMENT OF WORKS FOR OBTAINING THE SUPPLIES OF CANALS AS HEADS, ESCAPES, WEIRS, &c. &c.

1. BACIALLI, GIOVANNI—* Opuscolo sulle Pescaje (Temporary Dams).
2. LECCHI, ANTONIO—* Trattato dei Canali Navigabili.
3. FERRARI, FRANCESCO BERNARDINO—* Dissertazione sopra la costruzioue delle Chiuse (Dams) per la derivazione dei Canali Regolati.
4. MASETTI, GIOVAN BATTISTA—* Notizie istoriche intorno all' origine ed alla formazione del Canale Naviglio di Bologna.
5. BRUSCHETTI, GIUSEPPE—* Storia dei progetti e delle opere per la Navigazione interna del Milanese.
6. PAREA, CARLO—* Sulla Navigazione interna del Milanese.
7. FOCACCI, FRANCESCO—* Metodo per correggere le altezze eccessive delle pescaje e per migliorare gl' Idraulici Edifizi per mezzo principalmente di Cateratte oscillanti.
8. POLENI, GIOVANNI—* Delle Pescaje, o cateratte di lati convergenti, per le quali si derivano le acque dei fiumi.

N.B.—Copies of each of the works marked by an asterisk have been procured for deposit in the Library of the College of Civil Engineers at Roorkhi, on the Grand Ganges Canal.

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* The original list, as given to me by Baron Plana, bears the following title: " Elenco di opere sulle Pratiche Techniche degl' Ingegneri Italiani e sulle Discipline Legali nel derivare, condurre ed applicare le acque agli usi industriali ed agricoli."

SECTION II.—On the Formation of Conducting Channels, Bridges, Siphons, Aqueducts, &c.

1. Cavalieri, San Bertolo—* Edifizi destinati al regolamento ed alla condotta delle Acque. Capo xiii. Sez^{e} II. Libro III. delle sue Instituzioni d'Architettura Statistica ed Idraulica. Bologna, 1827.
2. Alberti, Giuseppe Antonio—Istruzioni pratiche per l'Ingegnere Civile. Venezia, 1782.—Vedi anche Bruschetti e Lecchi gia citati.

SECTION III.—On Outlets, Modules, Works of Distribution, and Measure of Water.

1. Guglielmini, Domenico—* Della misura delle acque correnti.
2. Ferrari, Francesco Bernardino—* Sulle Bocche che estraggono acqua dai Navigli, ossia Canali Navigabili di Milano.
3. Tadini, Antonio—* Del movimento e della misura delle acque correnti.
4. Bemareggi, Isidoro—* Tavole Paraboliche.
5. Masetti, Gian Battista—* Descrizione, esame, e teoria di tutti i tachimetri idraulici fino ad ora conosciuti.
6. Dello Stesso—* Della misura delle acque correnti per le Bocche di derivazione e per gli alvei di corso equabile.
7. Castelli, Benedetto—* Della misura delle acque correnti.
8. De Regi, Francesco Maria—* Uso della Tavola Parabolica per le bocche d'irrigazione. Milano, 1804.
9. Tadini, Antonio—* Dell'esito di una memoria idraulica.—Vi si ragiona delle pratiche Milanese e Cremonese per la dispensa delle acque correnti. Milano, 1815, in 8vo.
10. Brunacci, Vincenzo—* Sulla dispensa delle Acque.
11. Turazza, Domenico—* Trattato d'Idrometria ad uso degl' Ingegneri. Padova, 1845.
12. Colombani, Francesco—* Manuale pratica d'Idrodinamica con due appendici contenenti il testo di alcuno Leggi Austriache e Sarde relative alle Acque. 2a Edizione. Milano, 1845.
13. Cocomelli—Istituzioni d'Idraulico teorico-practica. Parma.
14. Sereni—Trattato d'Idrometria. Roma.

SECTION IV.—On the use of Water in Industry for the movement of Mill-Wheels and other Works.

1. Masetti, Gian Battista—* Trattato teorico-sperimentale delle Ruote Idrauliche e dei Mulini da Grano e da Pistare.
2. Cadolini, Giuseppe—L'Architettura pratica dei Mulini. Milano, 1838.
3. Lombardini, Elia—* Sull' Applicazione dell' acqua ai motori idraulici in Lombardia.

SECTION V.—APPLICATION OF WATER IN AGRICULTURE, IRRIGATION, DRAINAGE, LAND IMPROVEMENT, WARPING, ALLUVION, SANITARY WORKS, PROTECTION FROM INUNDATIONS.

1. CATTANEO, CARLO—*Intorno ad alcune instituzione agrarie dell' Alta Italia applicabili a sollievo dell' Irlanda. Quinto lettere a Roberto Campbell, Vice-Console Brittanico. Del tomo XVI. del Giornale dell' I. R. Istituto Lombardo di Scienze, Lettere ed Arti. Milano, 1847.
2. TARTINI, FERDINANDO—*Memorie sul bonificamento delle Maremme Toscane. Firenze, 1838.
3. ZANOTTI, EUSTACHIO—*Sulle Paludi Pontine.
4. RAPPINI, GAETANO—*Relazione e voto sopra il diseccamento delle Paludi Pontine.
5. FOSSOMBRONI, VITTORIO—*Memorie idrauliche storiche sopra la Val di Chiana.
6. Do. do.—*Sopra la distribuzione delle alluvione.
7. Do. do.—*Relazione sopra il Lago d'Imecchio.
8. PAOLI, PIETRO—*Ricerche idrauliche relative alle Colmate.
9. LORGNA, ANTONIO—*Intorno al riparare dalle innondazioni dell' Adige la citta di Verona.
10. CASTELLI, BENEDETTO—*Considerazione sopra bonificazione delle paludi pontine.
11. Do. do.—*Considerazione sopra la bonificazione del Bolognese, Ferrarese, e Romagnuolo.
12. GUGLIELMINI, DOMENICO—*Della Natura dei Fiumi.
13. ALBIZI, LORENZO—*Sul bonificamento del paese di Pisa.
14. BORELLI, GIOVANNI ALFONSO—*Sulla Laguna di Venezia.—Sullo stagno di Pisa.
15. TORRECELLI, MICHELINI ED ALTRI—*Scritture e relazioni sopra la bonificazione della Chiana.
16. ZENDRINI, BERNARDINO—*Leggi, fenomeni, regolazioni ed usi delle acque correnti.
17. BOLOGNINI, EMERICO—*Dell' antico e presente stato delle paludi pontine. Remedi e mezzi per disseccarle.
18. SANI, ANGELO—*Sulle paludi pontine.
19. LORGNA, ANTOMMARIA—*Dissertazione del modo di migliorare l'aria di Mantova.
20. PRONY—Sur les marais pontines.
21. BEVILACQUA, ERCOLE—Informazioni sopra gli Argini, Scoli ed Adacquamenti dello stato Mantovano. 1737.
22. BERRA, DOMENICO—*Dei Prati del Basso Milanese a Marcita. Milano, 1822.
23. ROSSI, VINCENZO ANTONIO—Memoria per un piano di lavori pel definitivo bonificamento della Campagna Vicana. Napoli, 1843.

SECTION VI.—GENERAL NOTICES OF THE SYSTEM OF IRRIGATION IN DIFFERENT PARTS OF ITALY.

1. BRUSCHETTI, GIUSEPPE—*Storia dei Progetti e dei Lavori per l'irrigazione del Milanese. Lugano.

2. Nadault, de Buffon—*Des canaux d'Arrosage de l'Italie Septentrionale dans leur rapports avec ceux du midi de la France. Paris, 1843–44.
3. Masetti, Agostino—Notizie statistiche sulle acque di Lombardia.
4. Venturelli—Notizie statistiche sulle acque del Veneto.
5. Mauny, de Mornay—*Pratique et Législation des Irrigations dans l'Italie superieure et dans quelques Etats de l'Allemagne. Paris, 1844.
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2. ——— ———Decreti secoli XV. circa jura aquarum cameralium-Mediolani, in 4to.
3. ——— ———Legislazione anteriore al 1796 sui fiumi Lambro e Muzza per le irrigazioni.
4. ——— ———Do. do. do. sul fiume Olona.
5. Robecco, G. Maria—Relazione alla modellazione delle bocche del fiume Muzza.
6. Poleni, Giovanni—Parere intorno alla maniera piu adattata di dividere le acque di Muzza.
7. Romagnosi, Domenico—*Della Condotta delle Acque. Milano, 1833.
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9. ——— ———*Statuti di Milano.
10. ——— ———Consuetudini di Carlo V.
11. ——— ———*Regolamenti Italici. 20 Maggio, 1806.
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12. Giovanetti, Giacomo—*Du Regime des Eaux. Novara, 1843.
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15. Ascona, Antonio—Manuale teorico-pratico sull' uso delle acque pubbliche e private. Milano, 1836.
16. ——— ———*Manuale dell' Acquajuolo (senza nome d'autore.) Milano, 1839.
17. ——— ———*Codici civili del Regno Italico, Francese, Austriaco e Sardo.

APPENDIX B.

SKETCH OF THE IRRIGATION SYSTEM OF NORTHERN AND CENTRAL INDIA.

It has appeared to me probable that a short account of the system of irrigation, which has been extended so widely throughout the north-western provinces of British India, may not be an unacceptable addition to the details of the Italian system given in the body of this Report. It is, of course, neither the place nor the occasion to describe at present the canals of India in technical or minute detail. I contemplate now nothing more than a popular sketch which may interest the general reader, and perhaps serve to make better known than they yet are, a series of works more likely, from their relations to the material prosperity of the country, and from their permanent nature, to perpetuate the memory of English dominion in India, than any others hitherto executed.

I would willingly have made this sketch embrace the entire subject of irrigation in India, furnishing illustrations from the south as well as from the north; for in the former portion of the peninsula, and under the control of the government of Madras, great works have been executed, well worthy of notice. But with the system of irrigation as pursued in Southern India, I am not personally familiar; and although I endeavoured to obtain the assistance of a friend who had been engaged in such works, difficulties, arising from the want of records and the necessary numerical data, interfered to prevent this aid being given. I therefore restrict myself to a notice of those works executed in the irrigated region with which I am best acquainted; and I do this with the less regret, as I trust the time is not far distant when the government of India will itself take measures to have prepared a detailed and satisfactory account of the whole of its

operations for improving the productive resources of its different provinces, whether in the north, the south, or the centre.*

The notice of the system of irrigation in the last-mentioned region, hereafter given, has been prepared, at my request, by my friend and brother officer, Lieutenant Henry Yule, of the Bengal Engineers. It gives some details of one of the most interesting examples of the happy influence of irrigation, at once in its moral and material aspects, which our experience in India supplies.

That districts, less wild, perhaps, in their natural features than in the character of their inhabitants, should have exhibited so speedily the civilising effects of exertions like those of Colonel Dixon, is a testimony so powerful to the efficacy of the means employed, that I refer to it with sincere pleasure.

SECTION I.—Canals of Irrigation between the Rivers Ganges and Sutlej.

The first Indian canal of which we have any satisfactory record, dates from about the middle of the fourteenth century, and from a reign distinguished by many improvements in legislative and fiscal policy; and although the primary object of its construction seems to have been the increase of imperial luxury, rather than the advancement of the prosperity of the country, yet Feroze Toghlak was too enlightened and benevolent to have been indifferent to the wants of the people over whom he reigned. The monarch, of whom it is recorded that he built "fifty dams across rivers to promote irrigation, forty mosques, thirty colleges, one hundred caravanserais, thirty reservoirs for irrigation, one hundred hospitals, one hundred public baths, one hundred and fifty bridges, besides many other edifices for pleasure or ornament," is not likely to have constructed with great labour the canal that bears his name, solely to supply the fountains, or water the gardens, or fill the wells, around his favourite hunting-palace of Hissar. His

* For the subsequent accounts of the canals of Northern India, I have simply recast an article of my own, printed in the 23d number of the *Calcutta Review*, omitting irrelevant matter, dispensing as much as possible with local and unfamiliar terms, and reducing to English equivalents the eastern measures and moneys therein employed.

good intentions, however, appear to have been early frustrated, since, in not much more than half a century after his death, the waters of his canal ceased to flow beyond the lands of Khythul, and the neighbourhood of Hissar returned to its original sterility.

The position of the head and the source of supply of Feroze's canal are matters of some doubt. The united testimony of the historians of the period, and uniform tradition, would lead us to believe that the supply was drawn from the Jumna, at its debouche from the range of the Sewalik Hills. But a most interesting and hitherto unknown document, obtained by Lieutenant S. A. Abbott from certain individuals in Dhatrat, a town on the western boundary of the district of Khythul, and published with a commentary by Lieutenant Yule, of the Engineers, tends to prove that Feroze drew his canal from the Chetang river, one of the drainage lines from the Sub-Himalayas, west of the Jumna. The document in question, which is a decree of the great Akbar, dated A.D. 1568, states that "the Chetang river, by which the Emperor Feroze, two hundred and ten years ago, brought water from the streams and drains in the vicinity of Sudhoura, at the foot of the hills, to Hansi and Hissar, and by which, for four or five months of the year, water was then available, has, in the course of time, and from numerous obstacles, become so choked that for the last hundred years the waters have not flowed past the boundary of Khythul—and thence to Hissar the bed has become so filled up that it is scarcely discernible:" in consequence of which state of affairs the emperor declares that his orders had gone forth during the previous year (A.H. 977, or A.D. 1567) "that the waters of the rivers and streams at the foot of the hills at Khizrabad (a town near to the present Delhi canal head), which are collected in the Sombe river, and flow into the Jumna, be brought by a canal deep and wide, by the help of dams, &c., into the Chetang, which is distant from that place about 130 miles, and that the canal be excavated deeper and wider than formerly, so that all the water may be available at the above-mentioned cities (Hansi and Hissar) by the year 978." It is a singular and somewhat unaccountable circumstance connected with Akbar's canal labours, that no mention of them is made by any of the historians of his reign; and that there is no

tradition even connecting his name with any of these ancient excavations, all of which are attributed to Feroze Toghlak: yet the original decree is said to present no good ground for suspicion, and its genuineness appears to receive confirmation from incidental circumstances. It would, therefore, appear that while Feroze constructed in 1351 the first Indian canal drawing an intermittent supply from the Chetang, it was to Akbar that the country west of the Jumna was indebted for a perennial stream drawn from the latter river.

It is impossible to read the "Canal Act," from which this information has been obtained, without regretting that it tells us but little more. At a time when problems, connected with the most important points of canal management, are pressing for solution upon ourselves, it would have been most interesting—it might have been most valuable—to have learned from an authoritative source, how such questions were decided by a mind like Akbar's, so comprehensive in its general views, so judicious in its minor details. The indications given, however, of his canal system are faint and feeble, and may be condensed into few words. A superintendent of canals was nominated, under the title of "*Mir-ab*"—the chief of the waters—with absolute authority throughout his jurisdiction. In his hands were vested the charge of the works, the distribution of the water; in short, all executive, revenue, and police details connected with the canal. The works would appear to have been constructed by forced labour, since all local officers are enjoined to furnish labourers, &c., without delay. To those, however, who complied with this requisition, water is promised during the season of cultivation and for the entire year. How this water was distributed is but faintly indicated. The *Mir-ab* is to determine the number of cuts necessary for each district, and, in a spirit of equal justice, he is directed to be careful that all parties, rich or poor, weak or strong, share alike. From other sources of information it is supposed that the amount of water rent was rated according to the time the heads of the cuts, probably of fixed dimensions, remained open. While the necessities of the cultivators were thus ministered to, the comfort of travellers was not forgotten; and it is directed, "that on both sides of the canal down to Hissar, trees of every descrip-

tion, both for shade and blossom, be planted, so as to make it like the canal under the tree in Paradise, and that the sweet flavour of the rare fruits may reach the mouth of every one; and that from these luxuries a voice may go forth to travellers calling them to rest in the cities, where their every want will be supplied."

With these brief and imperfect notices, this sketch of the Western Jumna canals to the time of Akbar terminates; and I pass over the succeeding sixty or seventy years—during which history is silent—to the reign of Shah Jehan, when new works were undertaken and completed with characteristic magnificence. The foundation of Shahjehanabad, and the natural desire to secure for his new capital and favourite residence the benefit of an abundant supply of water, induced the emperor to project the Delhi canal. In Ali Murdan Khan, so distinguished for his architectural taste and skill, he found an agent admirably qualified to give effect to his wishes; and although the first attempt proved a failure, the error was ably rectified by the ultimate selection of the best course which could have been adopted. Ali Murdan Khan's first line parted from Feroze's canal at a place called Madlouda,* and, pursuing a southerly course to Korana, it there entered an extensive natural hollow, the head of a great drainage line, and following that, in a highly embanked channel, as far as Gohana, it turned thence to the south-east by Jatoula, and, nearly on the existing line, entered Delhi. On the first opening of the new canal it was found that the embankments near Gohana were inadequate. The water, entering the great hollow there, found no efficient line of escape: it gradually rose over, and ultimately burst the banks, and, committing fearful devastation, destroyed the town of Lalpur, the extensive ruins of which are still to be seen in a hollow near Rohtuk. The inefficiency of the line having been thus fatally demonstrated, an entirely new channel was excavated from Rair to Jatoula, traversing the anticlinal ridge, or natural water-shed of the country, until it reached the vicinity of Bowana. Between this point and the city of Delhi, very low land intervenes; and, to carry the canal successfully across this hollow, much caution and skill were

* See "Map of the Canals of the Jumna," in the Atlas.

required. To give command over the supply, an escape or outlet was constructed at the upper extremity of the line of embankment, by opening which the surface level of the canal could be greatly reduced. Over the lowest part of the hollow the canal was carried by a masonry aqueduct, beneath which the drainage water of the country found escape. Clearing the low land, the canal wound for some distance along the base of the Aravulli Hills, and, at a favourable point, boldly crossed this ridge by a channel cut through the solid rock, no less than sixty feet deep at the crest. It then flowed through the city in a masonry bed, throwing off to the right and left innumerable minor streams, by which the residences of the nobles, and the various divisions of the city, were abundantly supplied. Throughout the great halls, and courts, and private apartments of the imperial palace, the plentiful stream was carried in numerous channels both above ground and below, supplying the graceful fountains, filling the marble baths, watering the rich fruits and flowers of the adjoining gardens, and adorning throughout its entire extent that truly regal abode in a manner worthy of the magnificent taste of its great architect.

The success of Ali Murdan Khan's labours was complete. The immense number of old water-courses along the whole line of the Delhi canal show to how great an extent the agriculture of the country benefited by its existence. Traditions of incredible amounts of revenue having been realised from villages on its banks still linger among the people there; and a proverbialism, current at Delhi, intimates that the clear returns from the canal were sufficient for the maintenance of twelve thousand horsemen. The permanent establishment, maintained for purposes of protection and repair, consisted of numerous workmen, one thousand foot and five hundred horse policemen, stationed under their officers at points three or four miles apart.

For about a century and a quarter after its original construction in 1626, the Delhi canal continued efficient; aged men informed a British officer, on survey duty in the neighbourhood in 1807, that they were finally deprived of canal water about the year 1753, in the reign of Alumgir II. The canal of Feroze had ceased to flow in Hurriana about 1707, and at Suffidún about 1740; so that the Mogul canals became practically extinct nearly

in the middle of the eighteenth century. The causes of this were simple. The general disorganisation of society, consequent on the decadence of the empire, rendered all measures of conservancy impossible ; the irrigated country was the constant battle-field of contending parties ; the works fell gradually into decay, and, amidst the struggles for existence that marked the reigns of the feeble successors of Aurungzeb, internal improvement was forgotten, and the system of irrigation, which, with greater or less efficiency, had existed for about four hundred years, became finally extinct.

Crossing now to the left bank of the Jumna, we have to sketch rapidly the ancient history of the Eastern Jumna, or Doab, canal. In common with the Delhi branch, the construction of this canal is ordinarily attributed to Ali Murdan Khan. Its head was established immediately under the Sub-Himmalayan, or Sewalik Hills, possession having been taken of a former bed of the river, bearing at this day the name of the "Old Jumna." Passing by the hunting-palace of Shah Jehan, called Badshah-mahal, it entered the bed of the Raipur Torrent,* and, carried thence in an excavated channel across the Jatunwala and Nowgong mountain torrents, it was thrown into a low ravine, near the town of Behut, which it followed until it reached the bed of the Muskurra river, near the village of Kulsia. Entering there upon the high land, the canal was carried past Saharunpur, Rampur, Jellalabad, Shamli, and other large towns, until it descended again into the valley of the Jumna, and, passing another imperial palace at Ranup, fell into the river nearly opposite the city of Delhi.

Although there is every reason to believe that the canal was excavated on the line described, it is very doubtful whether a supply of water was maintained in it for more than one season, if, indeed, for so long. There are remains of old embankments and aqueducts in the vicinity of Badshah-mahal ; and the palace itself was abundantly supplied with interior and exterior channels, with marble fountains of great beauty, and with suites of rooms adapted for cold and hot baths. But if there is any faith

* These streams at the base of the Himmalayas have the characteristics of the Italian "Torrenta." They are nearly all intermittent, being dry in summer, and subject to excessive floods during the rainy season.

to be placed in local traditions, the emperor's visit to this delightful retreat was exceedingly brief, and was curtailed for reasons amusing enough to be worth noting.

The visit of an emperor and his suite was no more agreeable in those days to the inhabitants of the adjoining country, than the presence of like high functionaries is now. An effort to relieve themselves from the infliction was therefore determined on. To have used force would have been folly, so stratagem was resorted to. Along the base of the lower hills, the goitre of the Alps is by no means an unusual disease. A large number of women afflicted with it were collected, and, when supplies were required for the emperor's harem, these women carried them in. The ladies naturally inquired concerning the cause of the shocking deformities presented to them, and the village women, as previously tutored, told them they would soon discover it for themselves, as no one could breathe the air, or drink the water, of these parts, without immediately having swellings of the same kind. There was instant commotion in the palace; the emperor was summoned, and entreated by the alarmed ladies to permit them at once to leave such a dreadful place. So earnest were they, that (the tradition says) the emperor at once sent them away, remaining himself for about a fortnight hunting tigers in the vast forests around. This was his first and last visit to Badshah-mahal.

The great difficulties at the head of the canal were doubtless beyond the skill of the Mogul engineers; and as there are no signs of irrigation in the southern part, and no masonry works of any kind, it may be concluded that, after the first opening, which is said to have been followed by great injuries to the towns of Behut and Saharunpur, the attempt to maintain the supply was abandoned.

About 1780, Zabita Khan, Rohilla, is said to have reopened the channel, and to have brought a stream of water, through the bed of the Kirsunni river, to the site of the great city projected by him in the neighbourhood of Jellalabad, Thanah Bhown, and Lohari, in the district of Muzuffernuggur. But his canal could have been open only for a few months; and with the first rain-floods it was doubtless seen that the difficulties were too formidable to be overcome.

We are now prepared to pass onwards to the consideration of the canal-works of the British government, but I may notice in passing one most interesting result, to which investigation of the historical records of the ancient canals has led. When describing the excavations of Feroze, Ferishta the historian mentions incidentally that the work-people found near the lower hills quantities of "giants' bones." For nearly two centuries and a half this seemingly fabulous statement passed unnoticed. To minds familiar with discoveries in fossil geology the old chronicle had, however, a faint gleam of significance; and, guided by its feeble light, English officers of the canal department re-examined the localities indicated, and found, associated with others of different dimensions, not "giants' bones," but bones most gigantic, from which, in course of time, they were able to add to the system of nature many new and strange animals before unheard of.

Soon after these provinces came under the British government, the propriety of restoring the Mogul canals began to be agitated. Attention was first drawn to the subject, it is said, by the offer of a gentleman (Mr Mercer) to reopen the Delhi canal at his own expense, on being secured the whole proceeds from it for twenty years. This offer was declined, and, about the year 1810, several officers were deputed to survey and report upon the lines both East and West of the Jumna. The reports, however, when submitted for the consideration of the Chief Engineers and Surveyors-General of the time, elicited such a variety of opinion from these officers that the government was paralysed, and the question dropped into temporary abeyance. It was resumed, however, with characteristic vigour during the administration of the Marquess of Hastings, who, in 1817, appointed Lieutenant Blane of the Engineers to superintend the restoration of the Delhi canal; and in 1822, Lieutenant Debude, of the same corps, to survey and report upon the Doab canal. The works were carried forward with energy from these periods; and I have now to detail briefly their nature and their results.

Commencing, then, with the Western Jumna canals, as the earliest in date and largest in dimensions of now existing canals, we find that Lieutenant Blane judiciously established the head

of supply at the highest possible point on the right bank of the Jumna. Taking possession of a deserted bed of that river, he carried the canal through it, and across a perfect network of minor channels, whose heads were closed by earthen dams until it reached the Patrala river, one of the Sub-Himmalayan drainage lines. Following the Patrala for a short distance, it left this river by an excavated channel; and, crossing the bed of the Sombe, another first-class mountain drainage line, it pursued its course through a new channel to the town of Búrea, where it fell into a natural hollow; and, skirting the high land westward of the Jumna, it followed the old line to Kurnaul, and thence to Delhi.

The original views of Government and of its officers were very restricted. Doubts were entertained of the ultimate success of the restored canal. Expensive works were discouraged; and the only object contemplated in Lieutenant Blane's time was to maintain a small supply in the Delhi branch. All the works undertaken were accordingly of a temporary and most imperfect character; earthen bunds were used for carrying the canal across the beds of the intersecting mountain-streams; few, if any, bridges were considered necessary, the canal being fordable throughout; and natural channels were invariably taken possession of, in spite of their defective levels and tortuous courses.

Labouring, however, with great zeal, and struggling with many difficulties, Lieutenant Blane had the satisfaction of seeing the canal re-enter Delhi after a suspension of more than half a century. He lived, however, only to complete his project, and, dying in 1821, was succeeded by Captain (now Major-General) Tickell, who maintained and improved the works executed by his predecessor.

The development of the Western Jumna canals, on the scale to which they have now attained, is, however, due to Colonel John Colvin, C. B., late of the Bengal Engineers, an officer of eminent professional talent, of great energy of character, and of unwearied zeal, whose memory is still affectionately cherished among the people for whom he laboured so long and so ably. Appointed in May 1820 to superintend the restoration of Feroze Shah's canal (an extension of Lieutenant Blane's project, which had been favourably received by government), he subsequently,

in 1823, succeeded to the superintendency of the works of irrigation generally throughout the Delhi territory.

A period of great activity now commenced. The evils due to the imperfections of the original design for the restored canals had already declared themselves. The increased supply required for Feroze's canal being brought by the same main channel as that for the Delhi branch, to their point of separation at Rair, it had become necessary to construct numerous bridges, and to raise massive embankments north of this point. The increased demand for water on both branches having at the same time led to their supplies being enlarged, the cross communication could no longer be maintained by fords; and these had to be replaced by bridges, built without interruption to the supply of water for irrigation, which could not be interfered with without great injury to the people and to government.

The grand difficulties, however, were experienced in the northern division of the canal, where the drainage waters of the upper and lower Himmalayas, collected in the beds of the Jumna, the Patrala, and the Sombe, had to be controlled and regulated. The inefficient system of carrying the canal across the beds of the drainage lines by means of earthen bunds, liable to be swept away by every flood, was a constant source of heavy expense and irretrievable delay. Yet so powerful in those days was the spirit of false economy, so decided the preference of temporary expedients to permanent remedies, on the part of the government and controlling authorities, that ten years were allowed to elapse before sanction was granted to the project for substituting an efficient masonry dam, in place of the sand and gravel bunds previously in use.

The history of this dam (situated at Dadupur, the headquarters of the Western Jumna canals) is a most interesting illustration of the varied difficulties and dangers entailed upon such a work, by its peculiar position in the midst of a knot of powerful torrents; and although to describe them at length would occupy more space than I can afford, I commend the narrative of these, as given by Major Baker,* to the notice of all who take pleasure

* See his *Memoranda on the Western Jumna Canals*, p. 8-18.

in learning how means, simple in themselves, have been employed by skilful men to produce great results, in controlling fierce floods, in protecting most important and expensive works, and in maintaining uninterrupted the supply of the canal, on which the prosperity of the country and the revenue of the state are equally dependent.

Although the ultimate issue of the struggle between the canal officers and the three great rivers encompassing the Dadupur works has been to vindicate the usual supremacy of mind over matter, and to place these unruly enemies under control, it must be remembered that they are ever ready to rebel, and to renew their attacks; but the mischief they can effect is foreseen, and, if the executive officers are duly supported, the result will not long be doubtful. They must not, however, be harassed by ignorant interference, by restricted means, by useless distractions of their thoughts and time to meet petty objections, or to conform to a mistaken economy; but they should be controlled wisely, and supported cordially in the execution of duties in themselves often wearisome and harassing enough both to body and to mind.

The defects of alignment and level in the southern parts of the Western Jumna canals have exhibited themselves in a manner sufficiently distressing. The increase of silt deposits in some parts, and of supply of water in all, requiring the formation of high embankments, has led to the interception of the natural drainage of the country, and to the consequent formation of many unseemly and malarious swamps. Most vigorous efforts have, however, of late years, been made to remedy these evils, and none can be more anxious for their removal than the canal officers themselves. If the remedial measures adopted have not at all times been either so judicious or so successful as might have been desired, the march of improvement has, in reality, been but little impeded by such partial failures; and if the same general system of intelligent activity as at present exists continues to prevail, many (if we cannot say all) of the admitted evils now existing will be removed before many years pass by.

I annex a tabular abstract of works of various kinds on the Western Jumna canals, which will give the reader an idea of their nature and extent.

1.—Abstract of Works on the Western Jumna Canals.

								Bridges.			Station-Houses.							Irrigation Outlets.						Bridges, for Millstreams, Escapes, and Marshes.		
	Masonry Dams.	Stop Dams.	Escapes.	Lock Gates.	Overfalls.	Weirs.	Aqueducts.	Suspension.	Masonry.	Timber.	1st Class.	2d Class.	Depôts.	Grain Stores, &c.	Mills.	Workshops.	Chief Watercourses.	Single.	Cistern.	Drains and Inlets.	Masonry Channels.	Revetments to Canal.	Arched Channel.	Timber.	Masonry.	Aqueducts.
Main Canal from Head to Rair, ...	1	..	2	..	..	..	..	1	4	6	10	11	1	1	1	2	2	...	...	...	...	.	...	2	9	...
																					At Delhi.					
Delhi Branch,.........	..	..	2	..	1	..	2	...	34	33	7	12	...	5	9	...	10	147	144	...	1	3	1	1	6	3
Bulla Do,..........	..	..	..	..	..	..	..	...	10	...	...	2	...	...	...	...	...	4	10	...	...	...	...	...	...	...
Hansi Do.,.........	..	3	..	2	..	1	..	...	41	2	7	11	...	1	...	2	4	...	...	6	...	...	...	...	5	...
Bahadera Do.,..........	..	5	..	..	..	..	..	...	14	...	3	3	...	...	...	...	...	116	12	...	...	...	...	...	...	...
Durba Do.,.........	..	1	..	..	..	..	..	...	11	...	1	1	...	...	...	...	...	76	...	30	...	...	...	...	...	...
Rohtuk Do.,.........	..	3	..	..	7	..	..	...	21	12	4	4	...	...	...	...	2	33	56	...	...	...	...	...	...	...
Butana Do,.........	..	..	..	..	..	..	..	...	24	1	2	5	...	...	...	...	...	49	25	...	...	...	...	...	...	...
Total,...	1	12	4	2	8	1	2	1	159	54	34	49	1	7	11	4	18	425	247	36	1	3	1	3	20	3

The main source of revenue from the canals west of the Jumna is of course the water rent. This rent is levied in two ways; 1st, On the area of the opening of the irrigation outlet at a certain rate, usually four shillings per annum per square inch, for natural irrigation, and half that sum for artificial irrigation; 2d, On the area of land irrigated, the rates being discriminating, both as regards the nature of the crop grown, and the kind of irrigation (whether natural or artificial) employed. On measured land they are as follow :—

	Natural irrigation per acre.	Artificial irrigation per acre.	
1. Fruit gardens, ...	£0 10 0	£0 8 0	per annum.
2. Vegetable gardens, indigo, sugar-cane, tobacco, cultivated grasses, and herbs, . .	0 4 0	0 3 0	per crop.
3. Rice, cotton, wheat, oats, Indian corn, vegetables (single crops), safflower, . . .	0 2 0	0 1 4	do.
4. Barley, oil seeds, pulse of all kinds, ...	0 1 4	0 1 0	do.

There are also variable rates for the different forms of irrigating machines used by the native agriculturists, so regulated as to give water at the general cost of one shilling per acre.

The following statement shows the gradual development of the revenue from water rent, up to the latest period for which returns are accessible to me :—

2. Statement of the Annual Amount of Water Rent levied on the Canals west of the River Jumna.

Previous to 1820,	£87	12	0	Brought forward,	£67,039	19	0
1820-21, ...	1464	12	0	1834-35, ...	11,406	10	0
1821-22, ...	2461	16	0	1835-36, ...	11,060	4	0
1822-23, ...	2145	16	0	1836-37, ...	15,317	12	0
1823-24, ...	3601	10	0	1837-38,† . . .	27,237	14	0
1824-25, ...	2664	12	0	1838-39, ...	18,964	8	0
1825-26, ...	4837	8	0	1839-40, ...	22,438	4	0
1826-27, ...	3397	10	0	1840-41, ...	22,581	14	0
1827-28, ...	3416	2	0	1841-42, ...	26,306	16	0
1828-29, ...	5295	4	0	1842-43, ...	27,930	0	0
1829-30, ...	5337	10	0	1843-44, ...	26,055	11	0
1830-31, ...	5770	0	0	1844-45, ...	23,102	4	0
1831-32, ...	5101	12	0	1845-46, ...	26,069	6	0
1832-33, ...	6580	9	0	1846-47, ...	26,252	18	0
1833-34,* . . .	14,878	9	0				
Carry forward,	£67,039	19	0	Grand total,	£351,763	0	0

* A year of partial failure of rain, and consequently of famine, in the non-irrigated districts.

† The great famine year.

Reference to this statement will show that the growth of the revenue from water rent was very slow. It was not indeed until the year 1833-34 that the income covered the expenses. The exceedingly unsettled state of the agricultural population, the constant fluctuations of the summary settlements of the government land revenue, and the novelty in many localities of canal irrigation, were the chief causes of this slow progress. The permanent settlement of the land revenue gave a great impetus to the extension of canal irrigation; and 1837-38, the year of the great famine, fatal as it was to districts not protected by canals, exhibits a remarkable increase—a fact pregnant with meaning. To illustrate the benefit of the canals to the community on this sad occasion, I subjoin a calculation of the gross value of agricultural produce saved by irrigation in the districts of the Delhi territory:—

3. Statement of the Gross Value of Crops grown on Land irrigated from the Western Jumna Canals in 1837-38, the greater part of which land would have been totally unproductive without the use of Canal Water.

1. *Crops of the Rainy Season.*			
12,806·25 acres of sugar-cane and indigo, at £8 per acre,	£102,450	0	0
47,026·25 acres of cotton, at £4, 16s. per acre, . .	225,726	0	0
46,256·25 acres of rice, &c., at £3, 16s. 6d. per acre, .	177,624	0	0
2. *Crops of the Cold Season.*			
199,375 acres of wheat, barley, &c., at £4, 16s. per acre,	957,000	0	0
Total, ...	£1,462,800	0	0

This return is compiled from one given by Major Baker, and is founded on actual measurement.* The rates are very moderate—less, indeed, than might have been assumed with perfect impartiality; and the result shows that nearly £1,500,000 sterling, in agricultural produce, was saved by the canal, of which about one-tenth, or £150,000, was paid to government as land and water rent; while the remainder supported in comfort, during a period of devastating famine, the inhabitants of nearly five hundred villages.

* In the Report of the Canal Medical Committee—Appendix, p. 66.

Any more striking illustration of the social and fiscal value of canals could not be given; and its force is enhanced, so far as the state is concerned, by the fact that the entire cost of the works (not including ordinary repairs and establishment) on the canals west of the Jumna, up to the present time, amounts only to £119,474; so that the returns of the year 1837-38 in land and water rent have covered the whole expenditure, leaving a surplus of nearly £26,800 from this source alone.

The next important item of canal revenue is the rent from flour-mills. These mills consist of substantial buildings of masonry, located near the large towns of Kurnaul, Delhi, and Hissar. The machinery is of the most primitive kind, being a small vertical wheel, with oblique horizontal spokes, slightly hollowed, on which the water impinges. Although these machines do not economise more than 30 per cent of the effective power of the water, and are liable to be interfered with during the rainy season by back water, yet they are so much preferred by the native community to any more complicated arrangement, that every attempt to supersede them by machinery of European forms has signally failed. The only one of the latter which appears likely to compete successfully in native estimation with the present form of wheel, is the turbine, which it is intended to introduce into general use.

The following statement shows the annual income from mills:—

4. Statement of the Annual Amount of Revenue from Mills on the Canals west of the River Jumna.

1822-23, ...	£302	13	0	Brought forward,	£18,097	17	0
1823-24, ...	686	16	0	1836-37, ...	2689	9	0
1824-25, ...	396	8	0	1837-38, ...	578	4	0
1825-26, ...	299	2	0	1838-39, ...	973	4	0
1826-27, ...	368	5	0	1839-40, ...	1456	13	0
1827-28, ...	1167	13	0	1840-41, ...	952	8	0
1828-29, ...	1626	14	0	1841-42, ...	820	7	0
1829-30, ...	1978	12	0	1842-43, ...	988	5	0
1830-31, ...	1946	8	0	1843-44, ...	1259	17	0
1831-32, ...	1900	4	0	1844-45, ...	822	0	0
1832-33, ...	1923	16	0	1845-46, ...	1325	1	0
1833-34, ...	1388	4	0	1846-47, ...	1470	19	0
1834-35, ...	1829	8	0				
1835-36, ...	2283	14	0	Grand total,	£31,534	4	0
Carry forward,	£18,097	17	0				

Mill rent, it will be seen, varies much. It is mainly dependent on the demand for irrigation, and when that is great, the supply of water for the mills is necessarily small. The return to the state on capital invested in mills has, however, been very great—the total expenditure having been nearly £5340, and the average revenue, as shown in the statement, being nearly 23 per cent per annum.

The pastoral villages in the district of Hissar depend entirely on the canal for the means of watering their cattle; and a small revenue is derived from this source. All irrigating villages, paying revenue above £10 per annum, are allowed to water their cattle, and to fill their village tanks, free of charge. The revenue from watering cattle is shown in the following statement:—

5. Statement of Annual Revenue from Watering Cattle on the Western Jumna Canals.

1828-29	£377	5	0	Brought forward,	£2778	5	0
1829-30	356	16	0	1839-40	228	13	0
1830-31	296	17	0	1840-41	195	11	0
1831-32	421	1	0	1841-42	155	8	0
1832-33	339	12	0	1842-43	117	4	0
1833-34	125	14	0	1843-44	168	0	0
1834-35	166	18	0	1844-45	297	18	0
1835-36	214	11	0	1845-46	229	6	0
1836-37	219	14	0	1846-47	168	14	0
1837-38	76	0	0				
1838-39	183	17	0	Grand total,	£4338	19	0
Carry forward,	£2778	5	0				

Although the Western Jumna canals are not used for boat navigation, a large quantity of timber, the produce of the forests of Deyrah Dhún, is annually rafted from the head to different points along the canals. The transit duties are exceedingly moderate; and the improvement in the condition of the people in the canal districts is very strikingly illustrated by the largely increased consumption of timber among them, in the construction of substantial and comfortable dwelling-houses. The interruption of the free course of the Jumna by the bunds for maintaining the supply of the canals east and west of the river, forces the whole of the river traffic into the Western Jumna canal for

some months of the year. The detail of transit duties is shown in the following statement:—

6. Statement of the Annual Amount of Transit Duties on the Western Jumna Canals.

1820-21	£1	8	0	Brought forward,	£1871	16	0
1821-22	8	8	0	1836-37	336	10	0
1822-23 to 1825-26	Canal closed for rafts.			1837-38	604	17	0
				1838-39	822	17	0
1826-27	50	0	0	1839-40	653	18	0
1827-28	101	6	0	1840-41	973	0	0
1828-29	118	14	0	1841-42	1150	11	0
1829-30	193	5	0	1842-43	793	9	0
1830-31	213	5	0	1843-44	557	1	0
1831-32	206	3	0	1844-45	659	17	0
1832-33	161	3	0	1845-46	783	0	0
1833-34	295	0	0	1846-47	679	19	0
1834-35	323	17	0				
1835-36	199	7	0	Grand total,	£9886	15	0
Carry forward,	£1871	16	0				

The Eastern appreciation of the luxury of shade, as evidenced in the decree of the Emperor Akbar quoted before, led to the banks of the canals being planted with trees of various kinds; but with the exception of a few varieties of ficus, these have all now perished, thus sharing the fate of those which lined the great imperial road from Agra to Lahore.

The formation of plantations early occupied the attention of the British superintendents. Something was done by Captains Blane and Tickell; but it was left to Colonel Colvin to proceed systematically in this useful duty. An allowance, originally of £200, afterwards increased to £300, per annum, was allotted to the plantations; and they have been spread over all parts of the canals to which water could reach. The trees planted are carefully selected, with the view of obtaining, from all of them, wood of value for economical purposes. The revenue derived from the plantations by sale of produce, although not large, has more than covered all expenditure upon them, and their ultimate value will be very considerable. The number of trees of all species exceeds 375,000, and their estimated value is nearly £56,700. The total expenditure by Government up to the present time amounts to only £2736, 6s., or about one-fourth of the revenue derived from the plantations, as shown in the annexed statement:—

7. Statement of Revenue from Sale of Wood, Grass, &c., the produce of the Plantations on the Western Jumna Canals.

1820-21	£63	11	0	Brought forward,	£1867	3	0
1821-22	118	1	0	1834-35	368	4	0
1822-23	74	2	0	1835-36	495	15	0
1823-24	65	12	0	1836-37	224	10	0
1824-25	54	10	0	1837-38	522	3	0
1825-26	37	1	0	1838-39	617	2	0
1826-27	71	7	0	1839-40	482	5	0
1827-28	146	1	0	1840-41	548	2	0
1828-29	128	19	0	1841-42	560	14	0
1829-30	114	5	0	1842-43	675	13	0
1830-31	126	10	0	1843-44	482	14	0
1831-32	212	14	0	1844-45	514	19	0
1832-33	265	2	0	1845-46	705	12	0
1833-34	389	8	0	1846-47	1016	15	0
Carry forward,	£1867	3	0	Grand total,	£9081	11	0

The only remaining source of revenue is from fines levied for breach of Canal Regulations. The value of water, especially during seasons of drought, leads to frequent infractions of the rules for protecting it, and for insuring its equable distribution, while the natural carelessness of native cultivators causes constant wastage, by neglect of their water-courses or other means. For the punishment of offenders in these and other ways, the superintendent of the canal and his assistants are vested with the powers of Joint Magistrates under Act VII. of 1845. The annual amount of fines is given below:—

8. Statement of Fines for Breach of Regulations on the Western Jumna Canals.

1820-21	£50	5	0	Brought forward,	£3658	19	0
1821-22	91	3	0	1834-35	430	6	0
1822-23	193	18	0	1835-36	260	7	0
1823-24	188	4	0	1836-37	293	0	0
1824-25	108	5	0	1837-38*	948	1	0
1825-26	242	6	0	1838-39	578	7	0
1826-27	328	6	0	1839-40	618	16	0
1827-28	447	2	0	1840-41	607	15	0
1828-29	284	14	0	1841-42	463	5	0
1829-30	280	3	0	1842-43	621	16	0
1830-31	250	17	0	1843-44	576	1	0
1831-32	246	6	0	1844-45	634	2	0
1832-33	341	0	0	1845-46	775	6	0
1833-34	606	9	0	1846-47	699	2	0
Carry forward,	£3658	19	0	Grand total,	£11,165	3	0

* The great famine year, when the avidity for water was such that no police measures could prevent its being stolen.

Having now given sufficient details of the revenues of the Western Jumna canals, I may next notice the expenditure upon them. This is divisible under three heads—viz., original works, including all new works of every kind; the regular establishment, being the salaries of the various classes of officers employed in the executive, revenue, and police departments; and current repairs, which are the expenses incurred in the maintenance of the works in a state of efficiency. I annex a statement of the expenses under these heads, from the restoration of the canals to the present time, adding for comparison a column showing the total direct revenue for the same period:—

9.—Statement of Annual Expenditure and Revenue on the Western Jumna Canals.

	Original Works.	Establishments.	Annual Ordinary Repairs.	Total Expenditure.	Total Revenue.	Deficiency.	Surplus.
To end of May 1821,	£14,216 9 0	£5,226 9 0	£531 19 0	£19,974 17 0	£1,687 12 0	£18,287 5 0	...
1821-22	...	1,909 11 0	658 13 0	2,568 4 0	2,679 9 0	...	£111 5 0
1822-23	...	2,761 5 0	930 6 0	3,691 11 0	2,626 11 0	1,065 0 0	...
1823-24	...	4,381 10 0	674 7 0	5,055 17 0	4,542 4 0	513 13 0	...
1824-25	...	5,338 2 0	418 3 0	5,756 5 0	3,223 17 0	2,532 8 0	...
1825-26	...	5,902 19 0	458 0 0	6,360 19 0	5,415 19 0	945 0 0	...
1826-27	414 9 0	6,448 9 0	683 1 0	7,545 19 0	4,215 10 0	3,330 9 0	...
1827-28	1,814 11 0	7,314 2 0	728 17 0	9,857 10 0	5,278 5 0	4,579 5 0	...
1828-29	...	7,421 12 0	966 3 0	8,387 15 0	7,831 12 0	556 3 0	...
1829-30	493 17 0	7,485 3 0	1,043 11 0	9,022 12 0	8,260 14 0	761 18 0	...
1830-31	...	7,712 2 0	1,625 5 0	9,337 7 0	8,603 18 0	733 9 0	...
1831-32	...	7,971 17 0	2,040 2 0	10,011 19 0	8,088 3 0	1,923 16 0	...
1832-33	...	8,224 4 0	2,295 19 0	10,520 3 0	9,611 3 0	909 0 0	...
1833-34	7,201 1 0	8,110 0 0	2,140 5 0	17,451 6 0	17,683 2 0	...	231 16 0
1834-35	9,027 17 0	7,764 13 0	3,616 10 0	20,409 0 0	14,525 7 0	5,883 13 0	...
1835-36	62,225 5 0	7,894 18 0	2,565 15 0	72,682 18 0	14,514 2 0	58,168 16 0	...
1836-37	338 6 0	6,549 4 0	2,189 5 0	9,076 15 0	19,080 18 0	...	10,004 3 0
1837-38	3,174 6 0	5,872 14 0	3,480 8 0	12,527 8 0	29,967 1 0	...	17,439 13 0
1838-39	4,604 8 0	5,720 3 0	2,107 7 0	12,431 18 0	22,140 0 0	...	9,708 2 0
1839-40	556 3 0	5,485 11 0	2,775 16 0	8,817 10 0	25,882 13 0	...	17,065 3 0
1840-41	3,118 2 0	5,706 13 0	2,578 11 0	11,403 6 0	28,858 14 0	...	17,455 8 0
1841-42	1,212 1 0	5,542 11 0	2,819 15 0	9,574 7 0	29,457 5 0	...	19,882 18 0
1842-43	2,511 11 0	5,310 9 0	4,391 10 0	12,213 0 0	31,126 10 0	...	18,913 10 0
1843-44	840 17 0	5,972 2 0	3,171 5 0	9,984 4 0	29,099 7 0	...	19,115 3 0
1844-45	263 18 0	6,706 19 0	8,968 19 0	15,939 16 0	26,031 3 0	...	10,091 7 0
1845-46	1,718 8 0	6,823 16 0	6,255 18 0	14,798 2 0	29,887 13 0	...	15,089 11 0
1846-47	5,676 18 0	7,185 18 0	5,397 13 0	18,260 8 0	30,288 10 0	...	12,028 2 0
Totals,	£119,405 7 0	£168,742 16 0	£65,513 4 0	£353,660 16 0	£420,607 2 0	£100,179 15 0	£167,136 1 0

The Establishment of the Western Jumna canals is necessarily large. The united length of the main lines is 445 miles, exclusive of the first-class water-courses, commonly called Rajbuhas, which, as well as the branch canals, are under the executive charge of the Canal Officers. With the minor, or village, water-courses no farther interference is exercised, than to require the proprietors to maintain them in such condition as that no wastage of water, or interruption to the communications of the country, shall take place.

The general control in all departments is vested in the Superintendent, whose duties are of a very miscellaneous description. As the Executive Engineer, all works are designed and constructed by him, under the authority of the Military Board, and of the Superintendent of Canals in the North-Western Provinces. As Collector of Revenue, he realises, by means of native local Agents, the various rents, formerly detailed, under the authority of the Chief Board of Revenue, and of the Commissioner of the division, to whom, in his capacity of Deputy Collector, he is subordinate; and, as Canal Magistrate, he has to protect the water and works under his charge from injury, his orders in this department being subject to appeal to the Sessions Judge. He has, therefore, many masters and many duties; but the former are generally liberal in their views, and, so far as may be, indulgent in their control; while the latter, though sometimes harassing, and always laborious, are most interesting and attractive to all who love their profession. The combination of powers in the person of the Superintendent is found to be productive of the best possible effects: his control of the revenue reacts in the department of works, by securing for him a legitimate influence among the people; and the entire separation of the canal from the local civil jurisdictions prevents, except in extreme cases, all collision, and secures cordial but independent co-operation. It might to a certain extent simplify accounts, and be a slight relief to the people in a single form, to consolidate the land and canal revenues, and to collect them by means of the civil establishment; but this arrangement is open to so many objections, and would produce so much embarrassment and difficulty in carrying on the duties of the canals,

that its introduction would be followed by consequences far too injurious to the interests of the state and the people, to be in any degree compensated for by the trifling benefit to be anticipated from it.

Three assistant superintendents are in subordinate charge of divisions of the canal; and under them nine or ten European overseers, with the requisite native establishments, carry on the executive duties.

For revenue purposes, the canals are divided into ten districts, to each of which a native officer, called a Zilladar, with an adequate establishment, is appointed. The extensive introduction of the contract system, whereby the water-rent is fixed for twenty years, reduces the interference of these revenue officers with the people to a minimum.

The subordinate police establishment consists of keepers, stationed at intervals of two or more miles along the canal banks. These men have charge of the works and the water, and it is their duty to see that neither sustain any damage. The men in charge of irrigation have great opportunities of illicit gain; and to mention that they receive from Government the bare subsistence of 8 or 10 shillings per month, is sufficient to prove that such opportunities are not neglected. They are, in fact, of the same order as our other subordinate native establishments, and are neither better nor worse than their neighbours.

I annex a condensed abstract of the establishment of the Western Jumna canals:—

10.—Abstract of Establishment of Western Jumna Canals.

EXECUTIVE.

	Monthly pay. £	s.	d.
Europeans			
1 Superintendent,	60	0	0
1 First Assistant,	30	0	0
1 Second ditto,	20	0	0
1 Third ditto,	32	10	0
2 Conductors,	37	3	0
2 Overseers,	17	0	0
5 Assistant ditto,	32	10	0
Natives.			
3 Writers,	22	10	0
3 Accountants,	4	10	0
7 Assistant ditto,	7	0	0
11 Horsemen,	17	0	0
27 Footmen,	13	16	0
10 First-Class Keepers,	41	0	0
35 Second ditto,	17	12	0
8 Bricklayers,	8	4	0
8 Carpenters,	7	16	0
7 Blacksmiths,	7	0	0
4 Boatmen,	2	16	0
4 Letter-carriers,	9	12	0
2 Shopkeepers,	1	11	0
Total monthly expenses,	£353	10	0

REVENUE.

	Monthly pay. £	s.	d.
Europeans.			
1 Superintendent,	0	0	0
3 Assistants,	0	0	0
Natives.			
3 Writers,	15	0	0
2 Measuring Officers,	14	10	0
10 District Officers,	32	0	0
1 Treasurer,	2	0	0
1 Head-Writer,	5	0	0
3 Accountants,	4	4	0
7 Assistant ditto,	8	0	0
8 Measurers,	4	16	0
32 Horsemen,	48	0	0
58 Footmen,	31	6	0
129 First-Class Keepers,	51	6	0
	£216	2	0

POLICE.

	Monthly pay. £	s.	d.
Europeans.			
1 Superintendent,	0	0	0
3 Assistants,	0	0	0
Natives.			
3 Native Officers,	2	14	0
2 Non-commissioned Officers,	5	3	0
80 Men,	32	8	0
	£40	10	0

Statistical statements of the districts through which the Western Jumna Canals are carried have recently been prepared by the Collectors, under orders from Government; and in these, details of so much interest and value connected with canal irrigation are to be found, that I must advert to them here. For facility of reference, the different returns have been condensed into one form.

11.—COMPARATIVE STATEMENT OF POPULATION AND GOVERNMENT LAND REVENUE IN THE PORTIONS OF THE DISTRICTS OF THE DELHI DIVISION, IRRIGATED, AND NOT IRRIGATED, BY THE WESTERN JUMNA CANALS.

DISTRICT.	DESCRIPTION.	Area in acres.	Area in geographical square miles.	Total Area in square miles.	Population of each.	Total population.	Land revenue of each in pounds sterling.	Total land revenue in pounds sterling.	Population per square mile.	Land revenue per square mile.	Average population per square mile.	Average land revenue per sq. mile, in pounds sterling.
							£	£		£		£
Paniput,	Irrigated at Settlement,*	341,483	404	...	139,938	...	47,499	...	347	118	...	...
Delhi,	Ditto,	78,406	92	...	41,683	...	12,968	...	448	139	...	...
Rohtuck,	Ditto,	210,953	249	...	68,724	...	19,646	...	276	72	...	...
Hissar,	Ditto,	209,416	247	992	35,202	285,547	11,972	92,086	142	48	288	93
Paniput,	Irrigated since Settlement,	...	...	...	...	...	...	...	...	...	...	...
Delhi,	Ditto,	7,500	9	...	3,719	...	1,023	...	413	114	...	...
Rohtuck,	Ditto,	9,319	11	...	2,167	...	621	...	197	56	...	...
Hissar,	Ditto,	2,825	3	23	138	6,024	60	1,705	46	20	262	74
Paniput,	Unirrigated,	283,856	335	...	95,681	...	32,359	...	285	97	...	...
Delhi,	Ditto,	214,510	253	...	74,301	...	21,502	...	290	85	...	...
Rohtuck,	Ditto,	615,914	727	...	188,293	...	35,186	...	259	48	...	..
Hissar,	Ditto,	1,810,212	2,136	3,451	186,176	544,451	33,390	122,438	87	16	158	35
	Grand Total,	...	..	...	...	...	...	216,229	...	...	...	...

* About the year 1832.

The first point of interest this statement enables us to determine, is the proportion of the irrigated to the unirrigated areas in the different districts to which it applies. This proportion referred to the total areas, as being most convenient, is found to be as follows:—

	Total area in acres.		Irrigated area in acres.	
In Panípat, as . .	625,339	to	341,483	or, as 1 to 0.52
„ Delhi, as . .	300,407	to	85,906	or, as 1 to 0.28
„ Rohtuck, as . .	836,186	to	220,272	or, as 1 to 0.27
„ Hissar, as . .	2,022,453	to	212,241	or, as 1 to 0.1

From these results it appears that a little more than one-half of the whole district of Panípat is under the influence of the canals, while in Delhi and Rohtuck the proportion is reduced to one-third, and in the great sterile tract of Hissar it amounts only to one-tenth.

It is curious and interesting to compare for a moment these results on one of the great canals of Northern India, with those obtained in Northern Italy, as detailed in the body of my Report. I have there shown (p. 157) that the great plain of Piedmont, viewed as a whole, is irrigated to the extent of one-third, or nearly three-tenths of its entire area; while the rich portions of it, included between the Dora-Baltea and the Ticino, exhibit the higher proportion of one-half, or five-tenths of the surface under irrigation. In Lombardy (Report, p. 296), the zone between the Ticino and the Adda is irrigated over nearly nine-tenths; that between the Adda and the Oglio over two-tenths; and lastly, that between the Oglio and the Adige over somewhat more than one-tenth of their respective areas. We have not yet, therefore, in India any region so thoroughly watered as that which includes the provinces of Milan, Lodi, and Pavia. But the district of Panípat, having a total area equal to that of the united provinces of Ivrea, Vercelli, and Novara, exhibits a proportion of irrigated surface equal to the richest portions of these tracts, being, as above noted, under the influence of irrigation to the extent of five-tenths of its entire surface. Again, the districts of Delhi and Rohtuck, whose united superficies is very nearly equal to that of the entire plains of Piedmont, exhibit the same proportion of irrigation as was found to prevail in the

latter region, viewed as a whole—namely, about three-tenths of the total area. The district of Hissar, equal in extent to one-third of Lombardy, with the province of Verona, is irrigated over about one-tenth of its surface—a proportion differing but little from that existing in the zone between the Oglio and the Adige. I shall have to show hereafter the measures by which the now sterile deserts of the once fertile tract of Hissar may be restored to their original prosperity, and made to correspond, not as now with the worst, but with the second order of the Italian series at least.

The irrigated areas above referred to include the total areas of all the villages using canal water. But no village actually waters its whole area, parts being in fallow or waste, or occupied by inferior crops not requiring water. The proportion of the total area of an irrigated district actually watered is a point of much interest; and as I shall have occasion to employ it hereafter as a means of estimating the capabilities of projected canals, I give here the results arrived at on the subject.

Canal revenue being levied only on land actually watered, the measurements for this purpose are available as guides; and where contracts exist and no measurements are required, the money value of these contracts furnishes the means of making a fair approximation to the watered area. On these data the subsequent calculations are based, and the results as follow :—

	Total irrigated area in acres.		Area actually watered in acres.
In Paniput, .	as 341,483	to	127,100, or as 1 to 0.37
Delhi, .	as 85,906	to	34,686, or as 1 to 0.4
Rohtuck, .	as 220,272	to	84,653, or as 1 to 0.38
Hissar, .	as 212,241	to	105,062, or as 1 to 0.49

From these rates it may therefore be concluded that, as an average result, irrigating villages west of the Jumna actually water annually from one-half to one-third of their total areas. The best watered of all, in proportion to its area, is the irrigated portion of the district of Hissar, the chief towns of which were found in 1807 to be literally without an inhabitant. The canal here has almost called into being an active, contented, and prosperous peasantry, and exhibits within a limited area results which fully warrant further efforts.

In passing now to the consideration of the government revenue, and the population, it is to be noted, first, that the calculations of these are based on the total areas of villages of the different classes, as shown in the statement. Their results exhibit, in a very clear and decided manner, the beneficial influence of canal irrigation. The Western Jumna Canals had so nearly attained their maximum of irrigation before the permanent land-settlement took place, that but few villages have been brought under their influence since that event. Still, the increase of land revenue due to the use of irrigation is to be traced, as we find the average per square mile on villages irrigated since the settlement to be £74 per annum, while that in unirrigated villages is only £35, 10s.

It is also possible now, for the first time, to give form to a claim, always made by canal officers—to have credit given to their works for whatever increase of land revenue may be derived from canal villages, as compared with villages not enjoying the same advantages. The claim is a perfectly legitimate one, as the increase in question is due solely to the existence of the canals. Its amount in the case of the Western Jumna Canals may be calculated readily from the data in the statement; and as the point is of sufficient interest, I give the calculation here:—

12. STATEMENT OF ANNUAL INCREASE OF LAND REVENUE IN POUNDS STERLING, DUE TO THE WESTERN JUMNA CANALS.

			£	£	£	£	s.	d.
1. Paniput, ...	404	square miles, at	(118 —	97 =)	21 * =	8484	0	0
2. Delhi, ...	92	do., at	(139 —	85 =)	54 =	4968	0	0
— ...	9	do., at	(114 —	85 =)	29 =	261	0	0
3. Rohtuck, ...	249	do., at	(79 —	48 =)	31 =	7719	0	0
— ...	11	do., at	(56 —	48 =)	8 =	88	0	0
4. Hissar, ...	247	do., at	(48 —	16 =)	32 =	7904	0	0
— ...	3	do., at	(20 —	16 =)	4 =	12	0	0
Total annual increase of land revenue due to the canals, =						£29,436	0	0

* On referring to the *Statistical Statement*, p. 27, it will be seen that the annual land revenue from irrigated soil, is £118 per square mile; while from unirrigated it is only £97. The difference, £21, is therefore the increase due to the command of canal water. A corrected Statement, recently forwarded to me from India, by Lieutenant W. Wilberforce Greathed, of the Engineers, gives a total increase of a little more than £37,000 per annum as due to the Western Jumna Canals.

This sum, added to the direct canal revenue, as shown in Statement IX., gives a total increase of very nearly £60,000 per annum; and, supposing £17,000 to be expended in the canal and civil departments, we have a net income of £43,000 on an invested capital of £119,400, being 36 per cent.

Of the total land revenue of the four districts of which returns have been made, the sum of £93,791, out of £216,130, is derived from canal villages, and may be regarded as beyond all risk; the remainder, £122,438, is subject to the vicissitudes of the seasons, and, in the event of a failure of the periodical rains, would be much decreased, if not wholly annihilated; and the population, from whom it is drawn, must be supported by the government, migrate, or perish.

The excess of population in irrigated over unirrigated villages is very marked. The rate per square mile in Paníput and Delhi is high,* but not higher than the details in the body of my Report show it to be in the analogously situated plains of Northern Italy.

The rates in the Western Jumna districts are given below:—

In Paníput, . . .	as 347 to 285, or as 1 to 0.8
Delhi, . . .	as 448 to 290, or as 1 to 0.67
Rohtuck, . . .	as 276 to 259, or as 1 to 0.9
Hissar, . . .	as 142 to 87, or as 1 to 0.6
Average rates, . .	275 to 158, or as 1 to 0.57

Thus villages irrigating from the canal support on an average a population nearly two-fifths greater than that of villages not so irrigated.

Having now completed my account of the canals west of the Jumna, I may proceed to describe the Eastern Jumna Canal, which was first surveyed, with a view to active operations, in 1822, by Lieutenant Debude, of the Engineers. This officer, however, was removed to other duties immediately on the completion of his field work, and was succeeded by Colonel Robert Smith, of the Engineers, under whose orders the various works on the canal, as originally projected, were completed in the year 1830.

The Eastern had so far the advantage over the Western

* See Statement 9, p. 325.

Jumna Canals, that all the work considered necessary, the dams, bridges, escapes, &c., were finished before any water was admitted. It is not, however, to be concealed that Engineer officers had at that time most imperfect ideas of hydraulic works, and had no expectation of the difficulties in store for them.

The general alignment of the Eastern Jumna Canal was good; it occupied the highest land between the rivers Jumna and Hindun; it avoided entirely the valley of the former river, and, in its northern and southern portions, attention was paid to avoiding tortuosities of channel as much as was considered practicable. In the central part, however, the ancient bed was merely cleared out, and nearly all its vicious twists and turns left as of old.

The original excavation of the Eastern Jumna Canal was carried to a depth of four feet beneath the surface level of the country, without reference to the natural fall, which in the northern and southern parts of the canal was excessive.

On the 3d of January 1830, the canal was opened for the first time; and by the 20th of the same month, nearly every bridge north of Saharunpúr and south of Surrowli was in imminent peril of total destruction. Rapids established themselves at different points on the steep slopes between the bridges; and working back, as such rapids invariably do, they exposed the foundations, and in course of time would have completely undermined the works.

In addition to the injuries threatened to the masonry works, an evil even more formidable exhibited itself in the deposit, along the whole line of lower levels, of immense quantities of sand and river silt, brought from the upper portion of the canal. The bottom of the canal was being rapidly elevated, and, as the mischief was a progressive one, continual raising of the embankments was necessary to maintain the canal in its bed.

The task of rectifying these evils had devolved upon Lieut. (now Lieut.-Col.) P. T. Cautley, who, being assistant to Colonel Smith, had succeeded that officer on his departure for Europe in bad health.

Checking the effects of the retrogression of the levels on the bridges by means of rafts of timber moored in rear of such of

these works as were most immediately threatened, Lieut.-Col. Cautley lost no time in submitting a comprehensive project for remodelling the slope of the canal by the introduction of masonry descents, or falls. Looking to the general distribution of the slope of the country on which the Eastern Jumna Canal is carried, it was found that, while the total fall from the head of the canal to Selimpûr, where it rejoins the Jumna, was 421.07 feet in a distance of nearly 134 miles, 186.37 feet of this fall occurred in the first 28½ miles, and 45.6 feet in the last 11 miles, the remaining 189.11 feet being distributed over the intermediate distance of nearly 94 miles. There were, therefore, two steps of descent—the northern, dependent on the vicinity of the Himmalaya mountains, and the southern, on the drop of the canal near its terminus into the valley of the river Jumna.

The first object was of course to regulate the excessive slopes of these two steps.

In determining the rate of inclination to be given to the bed of the canal, two points had to be considered :—1st, That the slope should be sufficiently rapid to insure such velocity of current as would prevent the growth of aquatic plants in the canal, an evil of a serious nature in a tropical country, and, as we have found Italian experience to prove, equally so in a temperate one; and 2d, That it should not be too great for the adhesive powers of the bed itself, lest violent erosive action should result, and the very evil it was desirable to remedy should continue to exist. It was found that, on such soil as the canal bed presented, a slope ranging from 17 to 24 inches per mile would meet both these contingencies.

With exception to the first ten miles from the head, on which no danger was anticipated, the bed of the canal being there of boulders or hard shingle, the slope of the northern step was regulated by the construction of nine masonry falls, of which one had a descent of 15 feet, three of 8, two of 7½, and three of 4 feet each.

The excess of slope in the southern step was overcome by four falls, two being of 8 feet, one of 7½, and the last of 6 feet.

At a later period the slope of the portion of the canal, intermediate between the two steps, was regulated by two falls of 4

feet each; and in course of time the construction of four more will perfect the regimen of the canal bed.

The construction of these works was attended with the most gratifying success. Colonel Cautley's theory was that the sand or silt, whereby the lower levels of the central portions of the canal were being raised, was derived entirely from the erosive action of the stream on the bed in the northern division; and that so soon as this action was checked by the masonry falls, the silt deposits would be carried forward by the force of the current, and ultimately discharged into the Jumna. This theory was satisfactorily verified: all deposits have long since ceased, and those formerly in existence have on a distance of nearly twenty miles entirely disappeared. In the southern part of the centre division of the canal, the movement of the deposits is checked by the tortuosities of the channel, and other circumstances; but no very serious inconvenience is caused thereby.

The embankments raised to retain the canal in its bed are of the most massive proportions. They are about thirty or forty miles in length, and the canal flows between them at heights from six to ten, and even twelve feet, above the surface of the country. It was no unusual thing in former times for the canal to burst these embankments, and to convert the whole adjoining country into one wide waste of waters. Now, happily, such accidents are exceedingly rare, although they do still occasionally occur to keep the Canal Officers on the alert.

The northern division presented its own peculiar difficulties, in the control of the mountain drainage which crossed the canal; and here the struggle to maintain the works was even more arduous than on the Western Jumna Canals.

In addition to the floods, which entered the canal heads from the Jumna and the lateral Himmalayan drainage north of Nyashur, the point at which the excavated channel commences, the course of the canal was intersected by four first-class hill-torrents, the Raipur, the Jatunwala, the Nowgong, and the Muskurra rivers.

The floods of the Jumna and the lateral drainage from the sub-Himmalayas, north of Nyashur, were disposed of by means of the Fyzabad and Nyashur dams—works similar to that at

Dadúpúr, formerly referred to. The Raipur Torrent had an escape outlet provided for it in the canal bank. The Jatunwala and Nowgong rivers, uniting in front of the Nowgong dam, passed over that work; while the Muskurra was disposed of by a fourth dam at Kulsia.

To each of these works a long and interesting history is attached; but I must be satisfied with stating here that, amidst many difficulties, and not a few formidable accidents, they were maintained in a state of perfect efficiency by Colonel Cautley up to 1843, and subsequently, on this officer's removal to the higher appointment of Superintendent of Canals in the North-West Provinces, by the writer, who was then appointed his successor.

Much yet remains, however, to be done in restoring the drainage of the country in the centre division, which for about five and twenty miles is the blot on the fair face of this beautiful canal; for most beautiful in all other parts it truly is, with its broad road smooth as an English lawn, its double rows of trees drooping over the stream, its long graceful sweeps, its rich bordering of most luxuriant crops, its neat station-houses, and the peculiar care with which all its works are maintained.

The assessment system of the Eastern Jumna Canal is based exclusively on measurement. No contracts have yet been introduced, for the sufficient reason that, while such incessant changes of the levels of the bed were in progress, no contract could be maintained with even an approximation to justice. The water is distributed to the cultivators partly by cuts from the main canal, but chiefly by means of what are locally called "Rajbuhas," or principal water-courses, the joint property of the different villages, which have combined to pay for their construction.

These main channels are originally constructed and subsequently maintained by the canal officers. The requisite funds are supplied in the first instance by the Government, and are recovered from the villages by one or more payments, proportionate in amount to the benefit each proprietary community derives from the work.

The system originated on the canals west of the Jumna, where, however, it has never been carried to any great extent, in consequence of local obstructions. East of the Jumna it was

peculiarly successful; and, from its commencement in 1836, it continued to extend as speedily as the sum allowed by Government for annual advances would permit. This sum was at first very small, being only £500 per annum; but subsequently it was increased by degrees, until, on Major Cautley's delivering over charge of the canal in 1843, it had attained to £3000. Shortly afterwards a farther increase of £1500 per annum was authorised, and with these enlarged resources the system was extended, until in 1849 about 400 miles of these main channels had been completed.

Meanwhile, the advantages of the system had exhibited themselves so clearly, and had received such confirmation from the researches of the medical committee—which established the fact, that irrigation so conducted was liable to none of the evils traceable to the use of private water-courses from the main canal—that measures were taken to mature and submit a project for the immediate completion of the general plan, of which the existing channels were unconnected portions. This plan involved the establishment of two chains of main channels, one on each side of the canal, and parallel to it throughout its entire course. The terminus of each line was connected with the channel next to it, so that all surplus water from each was carried forward into the others, and brought into use without any loss.

On receiving the project, Government at once authorised the necessary advances, amounting to £12,000, with an additional sum of £3000 for mills; and the various works were shortly afterwards commenced and carried on with all practicable vigour.

When completed, the distribution system of the Eastern Jumna Canal will consist of 500 miles of channel, with all the needful works for cross communication, control of water, regulation of slope, &c., as on the main canal, although on a miniature scale. The canal will then be complete so far as its irrigating capabilities are concerned; and it is calculated that the extent of land actually watered by it will amount to nearly 160,000 English acres.

As regards the cost of these works, a general rate of about sevenpence per acre per annum covers all expenses of maintaining the lines; while it is found that their original construction has been effected at a total cost to the proprietors of about five

shillings per acre. The cost of exactly the same class of works on the Italian canals amounts to £15, 12s. per acre. The cultivator in the Milanese, therefore, pays above sixty times more for his minor works of irrigation than his Indian brother in the Doab.

The general advantages derived from this system of restricting irrigation to principal channels may be condensed under the following heads :—

1. The delivery of water on the best lines and levels.

2. Efficiency of control over the water by the reduced number of outlets from the main canal.

3. Economy of supply from the prevention of wastage of water by neglect of the cultivators.

4. Maintenance of the drainage lines of the adjoining country.

5. Extension of irrigation to localities to which no private water-courses could reach.

6. Prevention of village disputes by the entire charge of the channels being in the hands of the Superintendent of the Canal.

7. Combination of the full benefit of irrigation with the least possible unhealthiness.

I close this account of the works of the Eastern Jumna Canal, by annexing the accompanying abstract of them :—

1.—Abstract of Works on the Eastern Jumna Canal.

	Dams.			Aqueducts.		Bridges.						Station Houses.					Main Channels.		Canal Irrigation Outlets.
	Masonry.	Box work.	Drainage outlets.	Masonry.	Masonry Piers with Iron Channels.	Regulating.	Masonry.	Masonry with Timber Superstructure.	Inlets.	Canal Escapes.	Workshops.	1st Class.	2d Class.	Office Barracks, Guardroom, &c.	Falls.	Mills.	Number.	Length in Miles.	Masonry.
North Division	4	4	1	3	...	3	8	...	6	...	1	3	5	1	6	3	2	21	12
Centre Division	3	...	...	1	3	...	11	13	9	1	...	4	11	1	5	6	22	247	64
South Division	...	...	...	...	...	...	34	2	9	1	1	5	10	1	3	3	23	197	60
Total .	7	4	1	4	3	3	53	15	24	2	2	12	26	3	14	12	47	465	136

The sources of revenue on the Eastern are the same as on the Western Jumna Canals; the most important being, of course, the water rent. The gradual increase of this from the opening of the canal in 1830-31 is shown in the following Statement:—

2.—Statement of Annual Revenue from Water Rent on the Eastern Jumna Canal.

1830-31	£608	6	0	Brought forward,	£36,634	5	0
1831-32	755	2	0	1839-40	7,854	7	0
1832-33	2,210	14	0	1840-41	8,913	11	0
1833-34	4,696	9	0	1841-42	7,888	11	0
1834-35	3,791	16	0	1842-43	10,506	8	0
1835-36	3,708	2	0	1843-44	8,614	14	0
1836-37	4,430	16	0	1844-45	8,478	12	0
1837-38	9,131	11	0	1845-46	9,653	8	0
1838-39	7,301	9	0	1846-47	10,772	10	0
Carried forward,	£36,634	5	0	Grand total,	£109,316	6	0

The influence of the famine year, 1837–8, is as marked on the Eastern as we found it to have been on the Western Jumna Canals; and I subjoin a calculation of the gross value of the agricultural produce saved to the community on that occasion by the use of the canal water.

3. Statement of gross value of Crops grown on land irrigated from the Eastern Jumna Canal in 1837-38, the greater part of which land would have been totally unproductive without the use of the Canal water.

RAIN CROPS.			
12,986 acres of Sugar-cane, &c., at £8 per acre,	£103,888	0	0
4,500 acres of Cotton, at £4, 16s. per acre,	21,600	0	0
13,500 acres of Rice, &c., at £3, 16s. 6d. per acre,	48,937	10	0
COLD SEASON CROPS.			
65,431 acres of Wheat, Barley, &c., at £4, 16s. per acre,	314,068	16	0
Total value of crops,	£488,494	6	0

The gross value, therefore, of the produce saved by irrigation was nearly half a million sterling, of which about one-tenth, or £50,000, was government revenue, and the remainder the property of the agricultural community. The united Jumna Canals accordingly saved, during the year 1837–38, property to the value of nearly two millions sterling.

The next item of revenue is from mill rent, of which a statement is here annexed:—

4. Statement of Annual Revenue from Mills on the Eastern Jumna Canal.

1830-31	£88	9	0	Brought forward,	£4356	3	0
1831-32	247	13	0	1840-41	329	15	0
1832-33	490	5	0	1841-42	373	7	0
1833-34	443	11	0	1842-43	619	8	0
1834-35	333	10	0	1843-44	817	17	0
1835-36	472	16	0	1844-45	604	10	0
1836-37	515	9	0	1845-46	812	3	0
1837-38	500	2	0	1846-47	783	16	0
1838-39	435	16	0				
1839-40	428	16	0	Grand total,	£8696	19	0
Carried forward,	£4356	3	0				

The Eastern Jumna Canal mills are precisely the same as those formerly described on the Western Jumna Canals, and have been equally profitable to government and convenient to the people. The Saharunpúr mills, for example, which were built at a cost of about £450, are rented by public auction at £1, 4s. per day, and return about £300 per annum to the state, or nearly 67 per cent. The mills are left entirely in the hands of the parties renting them. No interference of any kind is exercised by the canal officers; but all questions of price, &c., are left to be adjusted between the renters and the parties using the mills.

The rapid fall of the country through which the Eastern Jumna Canal passes, renders the water peculiarly available as a prime mover; but as yet corn-mills only have been introduced. It is proposed to establish sugar, oil, and saw mills, and the experiment is certainly worthy of trial. It ought, however, to be borne in mind, that a great deal of valuable time will be lost in the first efforts of officers, who have but the imperfect descriptions in books to refer to as guides in the construction of machinery. Government should assist them by procuring working models of the most approved forms; and with these their progress would be more satisfactory to themselves, and more useful to the parties concerned, than if they are left to blunder on through numerous failures to a success ultimately imperfect, or at least only equal to what their first attempts, aided by good models, might have led.

The revenue from watering cattle is very trifling, as but few villages pay a less revenue than £10 per annum, and all above this standard are free from any charge.

The following statement shows the annual amount of this tem :—

5. Statement of Annual Revenue from watering cattle on the Eastern Jumna Canal.

	£	s.	d.
1830-31	£0	4	0
1831-32	10	14	0
1832-33	8	17	0
1833-34	5	4	0
1834-35	10	1	0
1835-36	6	7	0
1836-37	6	3	0
1837-38	18	19	0
1838-39	10	8	0
1839-40	6	11	0
Carried forward,	£83	8	0
Brought forward,	£83	8	0
1840-41	9	15	0
1841-42	15	7	0
1842-43	3	5	0
1843-44	13	14	0
1844-45	21	15	0
1845-46	10	7	0
1846-47	30	10	0
Grand total,	£188	1	0

One of the first effects of the silting up of the bed in the centre division of the canal, formerly described, was to close the waterways of all the bridges, the water standing in all cases above the crowns of the arches—in not a few above the roadways—and only kept from submerging the works by the parapets. With such obstructions, navigation by boats was of course impracticable, and even for rafts the difficulties were very great—not so great, however, as totally to stop the transit. On the contrary, when in 1833 the superintendent issued an order prohibiting the passage of rafts, in consequence of the injury they did to the bridges when being forced through the submerged arches, the remonstrances of the merchants and others were so decided that the order was cancelled in 1836, and rafting again permitted, on the consideration that the amount of the transit duties would defray the cost of renewing the bridges. In 1846 the whole of the bridges in the centre division, and some in the south, were so remodelled as to give abundant waterway for boats and rafts. The transit duties have since risen, and continue to rise. Boats ply between Delhi and Saharunpúr, as yet only for canal purposes, in carriage of stores of all kinds; but it is hoped that the arrangements for opening the line to the community may soon be perfected.

To combine in such a manner as that both shall be efficient,

irrigation and navigation on the Eastern Jumna Canal is not to be expected. The first is so incalculably more important than the second, that when demand for water on the part of the cultivators exists, navigation must yield to it; and there will always consequently be a degree of uncertainty connected with the use of this line as a navigable one, which will impair its value.

The following statement shows the amount of transit duties:—

6. Statement of Annual Revenue from Transit Duties on the Eastern Jumna Canal.

1831-32	£0	18	0	Brought forward,	£137	2	0
1832-33	1	3	0	1840-41	—		
1833-34	0	14	0	1841-42	96	6	0
1834-35	—			1842-43	52	4	0
1835-36	—			1843-44	35	2	0
1836-37	8	17	0	1844-45	28	1	0
1837-38	26	4	0	1845-46	41	5	0
1838-39	42	13	0	1846-47	60	18	0
1839-40	56	13	0				
Carried forward,	£137	2	0	Grand total,	£450	18	0

The plantations on the Eastern Jumna Canal were commenced simultaneously with the canal itself, and have been extended systematically from that period up to the present time. The number of the trees in the canal plantations is nearly 292,000, and their present value is estimated at £14,680.

The total expense incurred by Government in the formation of plantations, up to April 1847, is £2214, 8s.; which sum, as will be seen by the following statement, has been very nearly covered by the sale of wood, &c., from the banks:—

7. Statement of Annual Revenue from Sale of Plantation Produce on the Eastern Jumna Canal.

1830-31	£59	5	0	Brought forward,	£919	6	0
1831-32	60	12	0	1840-41	247	0	0
1832-33	66	10	0	1841-42	164	10	0
1833-34	73	7	0	1842-43	194	0	0
1834-35	81	11	0	1843-44	141	7	0
1835-36	103	9	0	1844-45	170	8	0
1836-37	116	16	0	1845-46	172	11	0
1837-38	122	4	0	1846-47	184	4	0
1838-39	107	7	0				
1839-40	128	5	0	Grand total,	£2198	6	0
Carried forward,	£919	6	0				

In addition to the plantations of forest trees, grafted mango gardens have lately been established, with the view of introducing a superior fruit into the country adjoining the canal. Of these gardens five are in existence, containing about 300 trees each, and being from three to five acres in extent. The result of their establishment has been very satisfactory, the demand for grafts and fruit being much in excess of the means of supply. The native community, for whom they were chiefly intended, have shown their appreciation of them by purchasing a large number of grafts; and there is every probability that the intention of government in sanctioning the project will be fully realised.

I close the details of the revenue of the Eastern Jumna Canal by giving the accompanying statement of the amount of fines imposed for breaches of canal regulations:—

8. Statement of Annual Revenue from Fines on the Eastern Jumna Canal.

1830-31	£73	0	0	Brought forward,	£1722	5	0
1831-32	120	18	0	1840-41	432	5	0
1832-33	107	11	0	1841-42	378	10	0
1833-34	127	0	0	1842-43	368	6	0
1834-35	125	1	0	1843-44	453	10	0
1835-36	132	10	0	1844-45	573	12	0
1836-37	73	11	0	1845-46	308	12	0
1837-38	284	15	0	1846-47	343	8	0
1838-39	296	15	0				
1839-40	381	4	0	Grand total,	£4580	8	0
Carried forward,	£1722	5	0				

The expenses incurred in making and maintaining this canal have now to be shown; and to this end I shall adopt the same form as was employed for the canals west of the Jumna.

9. Comparative Statement

9.—COMPARATIVE STATEMENT OF ANNUAL EXPENDITURE AND REVENUE ON THE EASTERN JUMNA CANAL.

	Original Works.	Regular Establishment.	Annual Ordinary Repairs.	Total Annual Expenditure.	Total Annual Revenue.	Deficiency.	Surplus.
To April 1830	£31,123 19 0	£12,675 11 0	...	£43,799 10 0	...	£43,799 10 0	...
1830-31	...	2,965 17 0	£395 16 0	3,361 3 0	£829 7 0	2,531 16 0	...
1831-32	1,202 4 0	4,790 11 0	447 12 0	6,440 7 0	1,195 19 0	5,244 4 0	...
1832-33	1,115 6 0	2,787 0 0	1,092 19 0	4,995 5 0	2,884 13 0	2,110 12 0	...
1833-34	1,937 1 0	3,176 15 0	2,051 15 0	7,165 11 0	5,350 8 0	1,815 3 0	...
1834-35	4,025 13 0	3,099 19 0	2,429 11 0	9,555 3 0	4,342 2 0	5,213 1 0	...
1835-36	3,658 6 0	2,987 0 0	2,423 17 0	9,069 3 0	4,423 5 0	4,645 18 0	...
1836-37	2,659 18 0	4,104 0 0	3,027 8 0	9,791 6 0	5,151 14 0	4,639 12 0	...
1837-38	874 9 0	3,272 15 0	2,490 19 0	6,638 3 0	10,083 18 0	...	£3,445 15 0
1838-39	3,320 16 0	3,382 0 0	3,345 7 0	10,048 3 0	8,194 10 0	1,853 13 0	...
1839-40	113 17 0	3,346 4 0	4,051 17 0	7,511 18 0	8,855 18 0	...	1,344 0 0
1840-41	2,516 16 0	3,447 18 0	3,464 4 0	9,428 18 0	9,932 7 0	...	503 9 0
1841-42	9,939 13 0	3,479 5 0	3,064 9 0	16,483 7 0	9,116 13 0	7,366 14 0	...
1842-43	1,060 18 0	3,397 3 0	3,774 0 0	8,232 1 0	11,943 12 0	...	3,711 11 0
1843-44	11,960 10 0	3,123 1 0	3,587 13 0	18,671 4 0	10,076 7 0	8,594 17 0	...
1844-45	3,038 10 0	3,073 7 0	3,093 3 0	9,205 0 0	9,877 1 0	...	672 1 0
1845-46	1,142 14 0	3,390 1 0	3,405 8 0	7,938 3 0	10,998 13 0	...	3,060 10 0
1846-47	1,768 6 0	3,458 17 0	3,880 15 0	9,107 18 0	12,175 5 0	...	3,067 7 0
Totals,	£81,458 16 0	£69,957 4 0	£46,026 13 0	£197,442 3 0	£125,431 12 0	£87,815 0 0	£15,804 13 0

From the first column of this statement it will be remarked how continually, from the first opening of the canal up to the present time, new works have been in progress. Nor is the expenditure on this account at an end. The thorough drainage of the centre division, with several minor works, have still to be accomplished. When these are finished, however, the Eastern Jumna Canal will be nearly as perfect as a canal, with some irremediable defects of original construction, admits of being made.*

The duties of the different officers on the Eastern Jumna Canal are similar in all respects to those required from the establishment of the Western Jumna canals formerly described; and I need not therefore do more now than annex the following abstract:—

10. ABSTRACT

* I have always been of opinion that the result of the measures adopted for the extension of irrigation on the Eastern Jumna Canal would be to raise the revenue to between £18,000 and £20,000 per annum. The excellent administration of the canal by my friend and successor Lieutenant W. E. Morton, of the Engineers, promises to realise this expectation, as the income for the half-year ending the 31st October 1850 amounts to £8380, and a further increase may be expected.

10.—Abstract of Establishment of Eastern Jumna Canal.

EXECUTIVE.

	Monthly Pay. £	s.	d.
Europeans.			
1 Superintendent, .	60	0	0
1 First Assistant, .	30	0	0
1 Second do., . .	20	0	0
4 Assistant Overseers,	26	0	0
Natives.			
4 English Writers, .	19	10	0
1 Head Native Writer,	3	0	0
10 Ordinary do., . .	7	18	0
1 Non-com. Officer, .	2	0	0
10 Horsemen, . .	15	0	0
2 Native Doctors, .	3	0	0
1 Native Officer, . .	0	16	0
10 Overseers, . .	5	11	0
19 Do. Assistants,	7	12	0
2 Bricklayers, . .	2	2	0
3 Carpenters, . .	2	18	0
4 Blacksmiths, . .	3	4	0
86 First-class Keepers, .	34	3	0
3 Second do. do., .	1	8	0
48 Dam-Workmen, .	19	18	0
Total Monthly Expenses,	£264	3	0

REVENUE.

	Monthly Pay. £	s.	d.
Europeans.			
1 Superintendent, .	...		
Natives.			
1 Measuring Officer, .	7	0	0
1 Treasurer, . .	2	10	0
4 District Officers, .	14	0	0
4 Assistant do., . .	5	8	0
5 Native Writers (temporary), . . .	3	10	0
24 Footmen, . . .	11	16	0
3 Do. (temporary),	1	10	0
5 Horsemen, . .	7	10	0
7 Measurers, . .	3	10	0
6 Do. (temporary),	3	0	0
	£59	14	0

POLICE.

	Monthly Pay. £	s.	d.
Europeans.			
1 Superintendent, .	...		
Natives.			
1 Native Officer, . .	0	18	0
3 Non-com. Officers, .	1	16	0
18 Policemen, . .	7	4	0
	£9	18	0

The statistical researches carried on west of the Jumna were at the same time in progress east of the river; and I shall now, as

briefly as may be, exhibit their results, and the conclusions, as connected with the Eastern Jumna Canal, to which they lead. The following Table shows at one view the different details of the subject:

11.—COMPARATIVE STATEMENT OF POPULATION AND GOVERNMENT REVENUE IN THE PORTIONS OF DISTRICTS IN THE MEERUT DIVISION, IRRIGATED AND NOT IRRIGATED FROM THE EASTERN JUMNA CANAL.

DISTRICTS.	DESCRIPTION.	Area in acres.	Area in square miles.	Total area in square miles.	Population.	Total population.	Government land-revenue in pounds sterling.	Total government land-revenue in pounds sterling.	Population per square mile.	Land-revenue per square mile in pounds sterling.	Average population per square mile.	Average land-revenue per sq. mile in pounds sterling.
							£	£		£		£
Saharunpúr, .	Irrigated at Settlement,	76,802	91	...	79,488	...	8,716	...	873	95	...	...
Muzuffernuggur,	Ditto,	85,567	101	...	58,479	...	12,493	...	579	123	...	...
Meerut, . .	Ditto,	71,920	84	276	46,064	184,031	13,519	34,729	548	161	666	125
Saharunpúr, .	Irrigated since Settlement,	94,275	111	...	49,593	...	10,232	...	446	92	...	...
Muzuffernuggur,	Ditto,	15,249	18	...	7,956	...	2,113	...	442	117	...	...
Meerut, .	Ditto,	78,062	92	221	49,739	107,288	13,982	26,328	540	152	485	119
Saharunpúr, .	Unirrigated,	1,009,362	1192	...	414,564	...	87,794	...	348	73	...	...
Muzuffernuggur,	Ditto,	879,393	1038	...	428,694	...	92,589	...	413	89	...	...
Meerut, . .	Ditto,	458,896	541	2771	245,047	1,088,305	63,589	243,973	452	117	371	77
Grand totals, . .		2,769,526		3268		1,379,624		305,031				

The proportions of irrigated to unirrigated areas in the districts of the Meerut division, as deduced from this table, are as follow:—

	Unirrigated acres.		Irrigated acres.				
In Saharunpúr, as .	1,180,439	to	171,077	or as	1	to	0.14
Muzuffernuggur, as	980,209	„	100,816	„	1	„	0.11
Meerut, as . .	598,878	„	149,982	„	1	„	0.25

Thus Saharunpúr and Muzuffernuggur are irrigated to the extent of one-tenth, and Meerut to one-fourth, of their total areas, as given in the table. This proportion will be much increased when the Grand Ganges Canal is completed, as the irrigation of the eastern portions of these districts will then be provided for.

The proportions of the total areas of the irrigating villages actually watered are as below:—

	Irrigated acres.		Actually watered acres.				
In Saharunpúr, as .	171,077	to	32,780	or as	1	to	0.2
Muzuffernuggur, as	100,816	„	25,950	„	1	„	0.25
Meerut, as . .	149,982	„	47,975	„	1	„	0.32

The villages of these three districts, therefore, actually water annually nearly one-fifth, one-fourth, and one-third of their total areas respectively. As a general rule the cultivators in the irrigated portion of the Saharunpúr district are decidedly inferior to those in Muzuffernuggur, and these again to those in Meerut—the western portion of which latter district is scarcely less thoroughly irrigated than the best tracts west of the Jumna.

Very nearly one-half of the area now irrigated from the Eastern Jumna Canal has come under its influence since the settlement of the land revenue; and the effect of canal irrigation in increasing the income of Government is therefore very clearly proved. While the tracts of country in which irrigation has longest prevailed yield to Government an average revenue of £125, those to which it has been more recently introduced give £119, and the unirrigated lands only £77 per square mile per annum.

I give also for the Eastern Jumna the same calculation of the total increase of the land revenue as was before given for the Western Jumna canals:—

12. Statement of Annual Increase of Land Revenue due to the Eastern Jumna Canal.

				£	£	£		£ s. d.
1. Saharunpúr,	... 91	square miles	at	(95—	73=)	22	per mile,	= 2,002 0 0
„	... 111	do.	at	(92—	73=)	19	„	= 2,109 0 0
2. Muzuffernuggur,	101	do.	at	(123—	89=)	34	„	= 3,434 0 0
„	... 18	do.	at	(117—	89=)	28	„	= 504 0 0
3. Meerut,	... 84	do.	at	(161—	117=)	44	„	= 3,696 0 0
„	... 92	do.	at	(152—	117=)	35	„	= 3,220 0 0
Annual increase of land revenue due to the Canal,								£14,965 0 0

If to this sum the annual direct revenue of the canal be added, we have the total returns equal to very nearly £27,500 per annum. The expenditure has been £81,460; and, supposing the current expenses to be £8000, it appears that Government receives a net annual income of £19,500, on a capital of £81,460, or nearly 24 per cent.

Of the total land revenue of the three districts traversed by the Eastern Jumna Canal, about one-fifth—or £61,058, out of £305,031—is secured by it from risk of loss.

About one-fourth of the total population, or 291,319 out of 1,379,624 souls, occupy the canal villages; and the excess of rates per square mile in irrigated over unirrigated areas is as marked east as it was found to be west of the Jumna. The proportions are as below:—

	Irrigated per square mile.		Unirrigated per square mile.				
Saharunpúr, as .	604	to	348	or as	1	to	0.57
Muzuffernuggur, as .	510	„	413	„	1	„	0.8
Meerut, as . .	544	„	452	„	1	„	0.8

Saharunpúr is exaggerated in consequence of the population of the city of that name—the lands of which are irrigated—being included in the return; but the general result appears to be that the irrigated villages support a population about one-fifth greater than those which are unirrigated.

I have now but to notice, and that very briefly, the small canals or water-courses in the valley of Deyrah, as being the only other completed works at present in existence.

These are small, but most interesting canals, by which a portion of the great natural facilities for irrigation possessed by the beautiful valley of Deyrah has been taken advantage of.

The Bíjapúr watercourse, finished in 1841, is derived from the Tonse, a drainage line of one of the valleys of the great Himmalayan range, and irrigates a triangular tract of country about 7500 acres in extent, to the westward of the town of Deyrah, and bounded by the Bindal, Tonse, and Asun rivers. The channel, after leaving the Tonse, is carried boldly along the faces of the cliffs forming the sides of the ravine in which the river flows; and, sometimes by cutting through the rocks, sometimes by raising foundations from the bottom of the ravine, by tunnels in some places, by aqueducts in others, it is brought through most difficult ground to the high land at Dhakra, whence it proceeds to Gurki, and is there divided into two branches, one to the eastward, the other to the westward. For the first mile and a half the channel is of masonry, five feet wide, and three feet deep, and the remaining distance of eight or nine miles is in earthen excavation. The supply of water is about twenty-four cubic feet per second; the original cost of the works was £1592, 12s.; and the present net income is nearly £200 per annum, or about twelve per cent.

The slope of the country over which the watercourse passes is enormous, and is regulated by ninety-six masonry falls, varying from 2½ to 8 feet in height. Mills are established at favourable points, and return considerable profits to Government. The cultivators have not yet availed themselves, to the full extent, of the irrigating capabilities of the watercourse, the country being but thinly populated, and the necessity for irrigation variable.

The works were designed by Colonel Cautley, and executed, with much credit to himself, both as regards efficiency and economy, by Captain Henry Kirke, 12th Regiment, N. I.

The Rajpúr watercourse, designed and executed by the same officers, is intended chiefly to supply the town of Deyrah with good drinking water, although it has a branch for irrigation extending from the cantonments over the high land by the village of Dhurrumpúr, and irrigating a triangular tract of land to the eastward of the town of Deyrah, bounded by the Bindal, Ruspunnah, and Súswa rivers.

The masonry channel extends from the Ruspunnah, some

distance above the town of Rajpúr, to the large tank attached to the Sikh temple in the town of Deyrah, a distance of about seven or eight miles. North of the cantonment of Deyrah, before the irrigation branch leaves the main line, it is four feet wide, eighteen inches deep, with a slope of eighteen inches in every hundred feet, and a discharge of nearly eighteen cubic feet per second.

Ten corn-mills have been constructed near Rajpúr, and a circular-saw mill at the village of Dhurrumpúr.

The channel through the cantonment and town of Deyrah is two feet wide and eighteen inches deep, opening at short intervals into tanks and reservoirs for the convenience of the inhabitants. The excessive slope gives every facility for the construction of fountains; so that under the guidance of a local officer of taste, tact, and energy, the town of Deyrah might be made one of the most beautiful and most cleanly in India. I cannot say that its present appearance is worthy of its magnificent situation and almost unlimited capabilities, its beauties being nearly all due to nature, and very few to art.

The total cost of the works on the Rajpúr watercourse was £4298: the net annual returns are about £300.

These miniature canals in the Dhoon afford an excellent field for hydraulic experiments, and, in the hands of an officer whose mind had been directed to such questions, might be made to furnish data of an invaluable character. The manageable supply, the long lines of masonry channel, the varieties of slope and head waters, furnish facilities for investigation which are not elsewhere to be met with; and although these have not yet been taken advantage of, they probably will be, in course of time.

There is but little more to add to these details of existing canals of irrigation in the provinces subject to the government of Agra. We find that since these works first occupied the attention of the British authorities, they have expended upon them a sum of nearly £557,000, and have drawn from them in direct canal revenue nearly £546,000. They have brought under the influence of irrigation, and secured in a condition of the highest productiveness, an area of nearly 1,300,000 acres, yielding produce to the annual value of not less than two

and a half millions sterling, and supporting a population of 600,000 souls, of which a considerable proportion has been reclaimed from habits subversive of all good government, destructive to themselves, and mischievous to their neighbours. Great tracts of land, formerly waste, now sustain a dense, industrious, and thriving peasantry, well supplied with every material comfort they desire, placed beyond the reach of the vicissitudes of the seasons, bearing with ease to themselves a proportion of the state burdens considerably in excess of that imposed upon their less favoured fellow-subjects, and so sensible of the advantages they enjoy, that, even in the very worst of those localities, where inconvenience has arisen from the imperfections of the canal works, the general superiority of their circumstances is willingly admitted, and the desire for canal irrigation unhesitatingly expressed. So long as the control of the canals is vested in the local government, the progress of improvement will be encouraged to its utmost extent; and I think it is certain that as each year passes by, the admitted evils will gradually become less and less in number and extent, until, under the skilful employment of liberal expenditure, they shall have entirely disappeared.

I need say nothing here on the subject of the assessment systems adopted on the canals of Northern India, as this will be adverted to as fully as its existing condition will warrant in the second volume of my Report on Italian Irrigation, and I may therefore at once pass on to describe briefly the most important of those works which have recently been projected, or are at this moment in progress of execution, for turning to good account the waters of other rivers in the region now under notice.

The projected canals subdivide themselves naturally into two separate classes: first, Canals projected and in progress of execution; and second, Canals projected, but not yet commenced. It will be most convenient to dispose of the latter class first.

The most important projected canals are those designed for the irrigation of the country between the Jumna and Sutlej, and drawing their supplies of water, either directly or indirectly, from these rivers, or rendering available the minor streams by which the tract is traversed.

The first in order is a project for rendering available, for the

irrigation of a part of the districts of Hissar and Bhuttiana, the waters of the Cuggur* river, the most important of the sub-Himmalayan drainage lines. This river, rising in the Pinjúr valley, traverses in a south-westerly direction the protected Sikh states, the British territories in Hissar and Bhuttiana, the Bikanír state, and may be traced to the Sutlej in the Bhawulpúr country. During the cold season its supply is very small, so small indeed as to be of but little value in the upper part of its course, and of none in our own territories, the whole of the water being absorbed before it reaches these. It is upon the rain-floods that the irrigation of the adjoining country depends; and it is to regulate such floods, and to facilitate their progress through our own districts, that the project under description is directed.

The Cuggur river, like nearly all other sub-Himmalayan drainage lines, may be described generally as a stream flowing in a defined and very tortuous bed through a wide valley, varying in breadth from half a mile to three, or even four miles. The transverse section of the defined bed is of course exceedingly variable; but it is generally from about a hundred to a hundred and fifty feet in width, and from six to fourteen feet deep, in the part comprehended by the present project. The whole of the valley is usually submerged, or means are taken to cause it to be so, during the rainy season; and, from the effects of the saturation thus produced, the land bears a good cold-weather crop.

The Cuggur leaves the protected Sikh states in the vicinity of the village of Phúlund. During its passage through these territories, its waters are rendered available for irrigation by means of "Bunds," or earthen embankments carried across the bed of the river. To this most injudicious and destructive system the gradual deterioration of the bed of the river is principally due. North of each embankment, the silt-charged waters deposit annually new layers of sand, which in many places have already obliterated the defined bed, and caused the stream to spread over the valley, and to lose its power of forcing its way to the lower portions of its course. The wastage of water, so valua-

* Otherwise Ghuggur.

able in these arid tracts, is also frightful, from the total absence of all means of regulation or control. With the increased facilities late events have afforded us, measures ought to be taken to regulate the consumption of the waters of the Cuggur before they enter the British districts, so as to secure for the inhabitants of these their just share of the stream.

South of Phúlund, the Cuggur throws off a branch, called the Choya, or Chonya River; and all officers who have directed their attention to the question, agree in considering that this branch is in all respects more favourable for purposes of irrigation than the main stream.

The project submitted by Major Baker, of the Engineers, accordingly consists of two masonry dams or regulators, connected by a revetment wall. One dam, of seventy-eight feet water-way, crosses the bed of the main stream; the second, of fifty-two feet, will regulate the discharge into the Choya. Means are provided for distributing the flood waters between the two channels, the first floods of the season being passed down the Cuggur so as to fill the various lake-like depressions in its course, on the contents of which the people depend for water during the dry season.

The channel of the Choya is to be remodelled, by straightening its tortuous course, and so increasing its effective fall.

The expense of these measures is estimated at no more than £3426, while the return to government, by merely insuring the land rent from the fluctuations caused by deficiency of the ordinary supply of water, exceeds *two-thirds* of the estimated expense, being £2433; while the increase of supply, insured by the new arrangements, would provide irrigation for an additional extent of land amounting to 78,097 acres, and furnishing, at the very moderate assessment of a shilling per acre, a revenue of £3904, 17s. per annum.

Obstacles would appear to have arisen to the execution of this promising project; the chief of which seems to have been the fact, that certain villages in the vicinity of the site of the dam at Phúlund, including this site itself, were claimed by, and would probably be granted to, the Rajah of Pattiala. Still there could have been no practical difficulty in securing the management of the dam, and indeed the general regulation of the whole

course of the river, in the hands of English officers; and it can scarcely be doubted that the result would have been to improve greatly its capabilities.

A suggestion has been made to furnish to the Cuggur river a regular supply during the rainy months from the Delhi canal, from which the water can then without difficulty be spared. The scheme is practicable; and the propriety of its execution is simply a question of comparison between the expense of the works, and the benefits to be derived from them. As yet no measures seem to have been taken to procure materials for such comparison; but the plan is worthy of investigation, and should not be lost sight of.

The practicability of turning the waters of the Sutlej to use for purposes of irrigation early attracted the attention of our Mahommedan predecessors, and several traces of ancient canals from that river still exist. Such historical records as are available attribute most of them to the period of Feroze, so fruitful in works of irrigation; but it must be confessed that the allusions to his Sutlej canals are so indistinct, and in some cases so irreconcilable with the topographical features of the country, that it is almost impossible to make anything satisfactory out of them. I need not, therefore, do more than allude to these old works; and I now proceed to detail what has been done by the British Government.

To Major W. E. Baker, of the Bengal Engineers, belongs the merit of having first clearly and satisfactorily established the perfect practicability of a canal of irrigation from the Sutlej, and of having supplied such data as admit of a fair approximate estimate of the probable expense and returns from such a work being made.

Major Baker's project does not affect to be the best that could be framed. The brief period allowed for his survey made it impossible for him to examine the country in that degree of detail, which is a necessary preliminary to the actual execution of a great canal. But he has proved in the clearest manner the following most important facts: that an immense tract of British territory, now a desert, is admirably suited, both by the nature of its soil and the profile of its surface, to take the fullest

advantage of any means of irrigation that may be placed within its reach; that the introduction into this tract of a stream of water from the Sutlej is physically practicable; and that the probable benefit is so great as to warrant Government in undertaking the work, when means are available.

The tract of country whose improvement is contemplated by the Sutlej canal consists of part of the district of Hissar, and nearly the whole of Bhuttiana, called commonly the "Hard Desert." It is a bleak, wretched, and (without water) most sterile land. The wells are so deep that artificial irrigation is impossible: the water is so brackish and impure that none, save natives of the tract, can drink it with impunity; rains are scanty, and precarious vegetation is represented by a few stunted thorn-bushes, or a temporary crop of grass over the great parched plains. Under circumstances so ungenial, the population is necessarily scanty and lawless, deriving their subsistence chiefly from herds of cattle, and addicted to the marauding habits common to pastoral tribes.

The question here is, therefore, not to improve agriculture, but to create it; not to provide, as in the country between the rivers Ganges and Jumna, for the casual occurrence of an unfavourable season, but to supply by the resources of science a substitute for that deficiency of rain, which is the rule and not the exception; and finally, to enable an extensive and capable province to become, by its increased resources and the progressive improvement of its inhabitants, a source of strength and revenue to the state, instead of being, as now, a burthen and weakness.

The river Sutlej, after flowing for between three hundred and four hundred miles within the Himmalyan range, breaks through the low hills on the southern face of these mountains at the town of Roopur. For twelve or fourteen miles above this point the stream flows through a valley, varying from one to four miles in width, bounded by low ranges of hills, consisting generally of unconsolidated strata of clay and sand, intermixed with a species of nodular limestone or marl, known in India under the name of "Kunkur," and employed largely for various purposes in the department of public works. The discharge of the river is estimated at five thousand four hundred cubic feet per

second; the fall is about four feet per mile; and the bed is generally sandy, with occasional layers of shingle.

On judicious and satisfactory grounds the head of the proposed canal is fixed at a place called Búnga, thirteen miles above Roopur.

At this point traces of an ancient canal, said to have been excavated by Mirza Kúndí, the governor of Sirhind under Mahommed Shah (probably IV.), were found, and, with occasional interruptions, were observed as far to the southward as Sirhind.

To restore this old line, connecting it with the Sirhind river, whereby the stream would be carried in one main channel to Sungrúr, a total distance from the head of nearly ninety miles, appeared to Major Baker to be the most economical plan of delivering the water at a point from which it might be favourably distributed, by two branch canals, to northern Hissar, and the Bhuttí states.* The Hissar branch would be forty miles, the Bhuttiana branch a hundred miles in length.

The chief, indeed the only difficulties occur in the first forty miles from the head. These are three in number. The first is the want of permanence in the bed of the Sutlej, giving cause to anticipate some difficulty in maintaining the canal supply. This it is proposed to remedy by building a masonry dam across the bed of the stream, whereby considerable security against alteration would be obtained. The second is the deficiency of fall in the country from Búnga to Sirhind. This fall is only forty feet in forty-one miles; and, as the depth of digging at the canal head is six feet, the effective fall available for the canal channel is only thirty-four feet in forty-one miles, or 9.9 inches (say ten inches) per mile. This is a small slope certainly for an Indian canal; but it might be increased to twelve inches, by adapting planks or gates to the piers of the masonry dam, so

* That the plan proposed by Major Baker would be the cheapest available may be true, but that it would be the best is, I think, open to question. Nothing is more certain than that the occupation of old lines, and the employment of existing river-beds, have proved fruitful sources of evil on canals now in operation, and I believe that it would be true economy to avoid them. The levels are almost universally low, and the channels tortuous—both objections of serious importance in canals of irrigation; and I therefore venture to hope that the Sutlej canal, if ever undertaken, will be constructed independently of former lines, natural or artificial, even although this should entail some additional expense.

as to obtain during the season of irrigation five or six feet of additional head water. With even the lower regimen of slope, however, I believe the canal would be found efficient; and the difficulty is, in fact, of no great importance. The third is the very deep excavation, ranging in the first fifteen miles south of the Sissúwala torrent from thirty-two to twenty feet. It is considered probable that farther examination might lead to a better line being found south of Roopur—a very likely result; but even if unattained, the deep digging is not without its advantages, inasmuch as it admits of the hill drainage being all passed *over* the canal instead of through it, as is the case on the Jumna canals, where it is the source of so much evil and expense. On the whole, therefore, the difficulties of the project are not of serious consequence at their worst; and I doubt not but that the resources of the officers who may be employed on the works will prove adequate to vanquish them all.

The estimated expense of the Sutlej canal, with works on such a scale as to make it competent to a discharge of 2500 cubic feet per second, is £250,000. This estimate is a liberal and sufficient one, and would probably be found to exceed considerably the actual cost.

The probable returns, so far as the Government is concerned, will consist of water-rent, and such increase of land-rent as irrigated tracts under similar circumstances have been found to yield. As regards the first item, it is calculated that 2000 cubic feet of water will reach the irrigating districts; and, assuming the low average rate of the Western Jumna canals as the standard, this discharge is competent to the irrigation of 312,000 acres. The average water-rent, west of the Jumna, is exactly two shillings per acre; consequently the return to Government from this source would amount to £31,200 per annum.

To form an approximate estimate of the increase of land-revenue which Government may anticipate, I avail myself of the statistical table of the Western Jumna canals formerly given, assuming that the influence of these canals on the district of Hissar may be taken as a guide in forming an opinion as to the influence of the Sutlej canal on the same district, and the adjoining one of Bhuttiana.

From the table we accordingly find that, while the rate of land-revenue per square mile of unirrigated localities in the district of Hissar is £15, that for irrigated tracts is £48, giving a difference in favour of the latter of £33 per square mile. Again, we find that the area on which the increased land-rent is calculated bears to the area actually watered the proportion of 2 to 1. Hence, as the Sutlej canal actually waters 312,000 acres, the increased land-revenue must be calculated on twice this area, or 624,000 acres, being 737 square miles. The increase of land-revenue may therefore at once be shown as below—737 square miles of irrigated land, at £33 per square mile, equals £24,321.

The total direct pecuniary return to Government from both the preceding sources would accordingly be £55,521 per annum on an invested capital of £250,000, or nearly 22 per cent.

These views are limited, however, to the benefits Government will derive from the project. We must now consider also the gain to the community, by bringing so large a surface of country, now a desert, under cultivation to the same extent as we find it on the Western Jumna canals. The benefit to the community will be represented by the gross value of the agricultural produce which the Sutlej canal will admit of being obtained from land which now yields none. Taking the results on the Western Jumna canals again as guides, I estimate the value of the produce alluded to as below:—

	CROPS OF THE RAINY SEASON.		
13,000	acres of sugar-cane, . .	at £8 0 0	=£104,000
52,000	„ of cotton, . .	at 4 16 0	= 249,600
52,000	„ of rice, &c., . .	at 3 16 6	= 198,900
	CROPS OF THE COLD SEASON.		
195,000	„ of wheat, barley, &c.,	at £4, 16s.	= £936,000
	Total gross value of crops on Sutlej canal, .		£1,488,500

Time will, of course, be required to create this property of the value of nearly one and a half millions sterling per annum; but it is only necessary to compare the state of the Hissar district, before the Western Jumna canals were restored, with its condition in its irrigating villages for the last ten years, to be satisfied that, with the supply of water—the first necessity of

agriculture in North-Western India—there will come a population able and willing to use it.

The benefits of the proposed canal now mentioned are such as admit of being approximately estimated in money ; but there are others which are measurable by no such standard. Among these are the moral benefits to be derived from introducing agricultural habits among a lawless and semi-barbarous people, converting them from wandering shepherds into settled, contented, and prosperous cultivators ; and the physical benefits to be anticipated from restoring fertility to a large tract of country, the increased moisture of which may probably so react as to secure more constant and more abundant supplies of rain over the adjoining districts, and thus improve the condition of those who cannot directly benefit by the canal. The numerous traces of former rivers unconnected with any mountain ranges, and the ruins of towns along their banks, show that these desert regions once enjoyed a far more generous supply of rain than they now do. We hope again to re-establish this happier state of things, and thus to check the deluge of sand which threatens to submerge so large a portion of their surface.

A canal having its head of supply to the westward of Lúdiana, near a place called New Tiharah, has also been projected, with the view of bringing into use the water of the Sutlej during the rains. This work has, however, on more careful examination of the country, proved to be, although practicable, so little likely to be profitable in comparison with its cost, that it has for the present been abandoned; and I need therefore only mention it here.

Crossing the Jumna, to the eastward, the only projected works are measures to take advantage of the streams which, rising in or near the Siwalic range, traverse the districts of Saharunpúr and Muzuffernuggur. It is very desirable to subject these streams to professional control, so that their waters may be rendered available for irrigation, without entailing the evils we have seen to prevail on the unregulated rivers west of the Jumna.

The extension of irrigation in the eastern portion of the valley of Deyrah, and the drainage of those great swamps which at present render this tract so fatal to human life, are also projected, but have not yet been undertaken. There is here a

great and most interesting field for improvement, and, until the projected drainage arrangements are carried into effect, this portion of the Dhún must continue, as now, to be worse than useless to the State and community. The facilities for drainage in the vicinity of the great swamps are remarkable: there are numerous channels of escape connected with the Ganges, the rapid slopes of the beds of which would make them most efficient; and nothing more is required than to select the most convenient of these, and to connect them with the swamps by drainage cuts of adequate dimensions, and properly adjusted levels. The work will not, it is true, advance very rapidly, as men can exist in these jungles only for three or four months of the year; but as each swamp is drained, the salubrity of the adjoining country may be expected to improve, and with each year of progress a larger period of time for active operations would be made available. It is now some years since the Court of Directors expressed their wish that the preceding operations should be set in progress; but the want of qualified men to superintend them has apparently prevented their being undertaken.

It remains now to notice the last class of the canals of the British Government—those, namely, which at this time are in course of execution.

The first works that claim attention are those for the drainage of the Nujufghur Jhíl, or lake, and the irrigation of the lands now covered by this great sheet of water.

The Nujufghur Lake extends from near the city of Delhi to some distance beyond Dholkote, and may be described as consisting of a main trunk of extremely irregular outline, and having a general south-westerly direction, about twenty-four miles in length, and from a quarter of a mile to three miles in breadth; and of two branches thrown off from the western border, the most northerly of which is about seven and a half, the other about fourteen miles in length, each being about half a mile in width.

The southern extremity of the main trunk expands into a large basin about three miles in diameter, into which the rivers supplying the lake discharge themselves. These rivers are two in number, the Badshapúr Torrent, which receives the drainage

of the hilly country south-east of the basin, and the Sahibí Torrent, which drains from the westward.

Professional attention appears to have been first turned to the improvement of the Nujufghur Lake about 1838, when Major H. M. Durand of the Engineers was appointed to survey the ground, and to report upon the subject.

The project submitted in May 1838 by this able officer was simple in design and efficient in detail. It contemplated the regulation of the floods of the Badshahpúr Torrent by means of a properly situated dam; the entire diversion of the waters of the Sahibí from the basin, except in years of extraordinary floods, and the excavation through the high land at the north-eastern or Delhi extremity of the lake of an escape cut to the river Jumna, of such dimensions, and such level at the head, as would admit of its draining the whole surface of the lake. This cut was of peculiar form, having a wide and shallow section in its upper portion to admit of the rain-floods passing off easily, and a narrow and deep one below, to secure the ultimate drainage of the most depressed portions of the bed. The project contemplated also the construction of a regulating bridge across this drainage-cut at a favourable point, by adjusting the gates or sluices of which, such quantity of water as was necessary for cultivation might be retained in the lake, and gradually discharged as the cultivators were prepared to take possession of the land laid dry.

This system was in exact accordance with the practice of the people in the villages bordering on the lake from time immemorial. Long experience had taught them the usual levels of the waters; on the ground just beyond the limit of continued submersion they planted sugar-cane, which ordinarily was luxuriant. As the waters of the lake dried up at the termination of the rains, the submerged ground was ploughed, and wheat was sown, and in this manner the cultivation followed the retiring waters, until the whole land usually laid dry was covered with crops.

In case of a failure of the rains, and to maintain the supply in the basin to the full extent required, Major Durand proposed to carry a cut from the Delhi branch of the Western Jumna Canal, and to depend upon it in cases of emergency.

Had this project been carried out, as originally designed, its

success would have been certain; but unfortunately, when it was submitted to the Military Board, that body so altered it that it proved a total failure; and for four or five years past the last state of the unlucky cultivators has been worse than the first, as, while their land-rent had been enhanced to the extent of upwards of £1000, their crops perished from want of water at one time, and from too much at another.

The expense incurred in the execution of such portions of Major Durand's project as were authorised appears to have been about £5800; and as Government had made these works the grounds for increasing the land-revenue, common justice required that efforts to render them efficient should be continued.

A new project was accordingly prepared in 1847 by Mr Battie, the executive officer of the works, which, after being approved of by Major Baker and Colonel Cautley, was immediately commenced, and is now most probably finished.

According to this project, an embanked channel, forty feet in width, will be carried along the lowest levels of the lake from the Delhi extremity to the gorge of the Dholkote basin. On reaching this point, the embankments turn to the right and left to meet the high land bordering the basin, which is thus entirely isolated irom the main trunk of the lake; and the waters entering it have no other means of escape than through the embanked channel. From the main channel two subordinate lines are carried along the lowest levels of the Bahadúrghur and Bussunnia branches of the lake; and means are adopted for collecting the country drainage-water into these different channels by means of duly-adjusted catch-drains. At the Delhi or northern end of the main channel the regulating bridge is placed, by which the water can be maintained at any desired height, the surplus being passed off by an escape cut to the river Jumna.

This project, it will be observed, differs from Major Durand's, in contemplating the entire recovery of the land forming the bed of the lake and its branches, with the exception of the space occupied by the embanked channel; and in substituting, for the submersion of the land for a certain time, irrigation in the ordinary manner, from a canal supplied by a large reservoir.

The contents of the Dholkote basin are calculated to be

sufficient for the irrigation of 24,000 acres, and the quantity of land to be permanently redeemed is estimated at 12,800; so that there will be but little risk of want of water except in extraordinary seasons, for which provision may be made by a cut from the Western Jumna Canal.

There is every prospect of Mr Battie's design being a successful one; and should it be so, it will secure to Government an annual revenue of about £1700. The estimated cost of the new works being £6000, and the total expenditure from first to last £11,800—supposing the cost of repairs and establishment to amount to £600 per annum—the Nujufghur Lake works will return to Government about 9 per cent on the capital invested in them.

There are several other large sheets of water in the Delhi territory which, to a certain extent, have been made available for cultivation, as the Chundaure, Kotillah, &c.; but these need not now detain us, as they are of no special importance. It is, however, most interesting to trace the extraordinary extent to which irrigation has in former times been carried on in this part of the country. Incredible numbers of ancient dams exist, and, wherever there was a possibility of collecting even the smallest body of water, there an embankment seems to have been formed, and a plot of ground of proportionate extent brought into cultivation. The immediate vicinity of the imperial city, with its court and army, probably gave an excessive stimulus to local agriculture, and led to these numerous works being constructed.

Continuing now our progress to the eastward, the next work we find in course of execution is the Kutta Puthur canal, intended for the irrigation of the western portion of the valley of Deyrah.*

This work was originally designed by Colonel Cautley in 1841, and was then laid aside on account of the financial pressure of the times. In 1847 the practicability of the work came again under discussion, and the writer was directed to superintend a new survey and design of the proposed work. The services of second-lieutentant Hutchinson of the Engineers were made available for the field work, and the new design, differing from

* This work is also, I presume, completed by this time.

that of Colonel Cautley only in details, is thus summarily described in my report upon it:—

"The Kutta Puthur canal, leaving the Jumna at a point on the left bank of that river, immediately under the village whence the canal derives its name, is 10 miles and 3712 feet in length. Its fixed supply of water is 80 cubic feet per second, and its fall, from the head to the bed of the Sitwala river, in which it terminates, is 52.59 feet, whereof 19.59 feet are absorbed by the initial digging and the slope of the channel, and 33 feet disposed of by masonry falls of 10, 5, 12, and 6 feet in depth respectively. In its course it traverses nineteen mountain streams, being drainage lines from the southern slope of the Himmalayas. These streams are annuals, being full only during the rainy season, and the canal crosses them by seven dams, with water-ways varying, as detailed in Lieutenant Hutchinson's report, from 10 to 100 feet, and 12 aqueducts, varying similarly from 10 to 90 feet. Its masonry channel, 10 feet in width and 3 feet in depth, extends for 19,713 feet (or nearly four miles) from the head, the remainder of the course being in earthen embankments, or excavations, as necessary. Three bridges for cross communication, two mill-houses for double sets of stones each, one first-class and three second-class station-houses, are provided for; and it is supposed that the whole series of works will be finished, and the canal opened, at the end of the year 1849. The estimated expense is about £8890." *

This canal has the same general characteristics as the other Dhún canals formerly described. It is carried along the faces of the cliffs rising over the Jumna in a masonry channel until it debouches on the upland of the western Dhún, at a place called Ambarí, from whence it is carried to the eastward in a direction generally parallel to the main range of the Himmalayas, and as near to its base as the levels permit, so as to bring the largest possible extent of land to the southward under irrigation. About 17,000 acres of the richest soil will ultimately be brought under the influence of the Kutta Puthur canal. This beautiful tract of country is now almost a waste—a few miserable-looking

* I suspect that this estimate has been materially exceeded in the execution of the work, from the difficulties of the line and other causes.

villages are scattered throughout it, but the population and cultivation are alike checked by the want of water for the common purposes of life. There is no adequate supply of drinking water for man or beast, and until this first necessity is supplied, any hope of improvement is of course vain. With it, and an abundant additional supply for irrigation, this part of the Dhún ought to be one of the richest in India.

The return to Government on the Kutta Puthur canal from water-rent alone is estimated at about 8 per cent on the capital invested. What the increased land-revenue would be it is difficult to say. At present this revenue is nominal; and whatever the amount of future assessment may be, it will be due entirely to the canal.

It only now remains for me to describe the grand Ganges Canal, the last and greatest of the canals of irrigation in progress of execution by the British Government. It will have been remarked that, in nearly all the works previously described, we have appeared as restorers rather than as original projectors. It is true that our restorations of the works of our Mahommedan predecessors are virtually new designs. Beyond the idea of the work, and the occasional adoption of the alignment they had selected, we have borrowed little from them; while the scale on which our restorations have been conducted, the numerous improvements that have been introduced, and the extensions that have been executed, may perhaps entitle us to the merit of originality.

The great Ganges Canal is, however, purely a British work, and occupies a field unoccupied before. That it will be the greatest work left to bear testimony to our national character it would be rash to assert, when railways are looming, however faintly, in the distance; but that, both in the scale of its construction, and in its influence on the material prosperity of the country, it will be one of the greatest, there can be no hesitation in affirming.

The early history of the Ganges Canal may be disposed of in a few sentences. The first officer who seems to have seriously contemplated the employment of the waters of the Ganges for irrigation was Colonel Colvin, of whose labours west of the

Jumna I have already had occasion to take notice. When in 1836 this officer, at that time superintendent-general of canals, delivered over charge to his temporary successor, Colonel Cautley, he strongly recommended that an examination of the country should be made, with a view to ascertain the practicability of the project. Such an examination was actually made during the course of the year by Colonel Cautley, but with results so little encouraging that the idea of the canal was temporarily abandoned by him. Colonel Colvin, however, continued hopeful of ultimate success, and recommended another examination, commencing at a higher point on the river than that first selected, and carried on a more circuitous line, so as to avoid some very impracticable country which had been met with.

The question, however, continued to be one rather of interesting speculation than of any practical importance, until the calamitous events of the great famine in 1837–38 attracted the serious attention of Government to the subject. The sacrifice of revenue to the extent of nearly a million sterling, the harrowing distress to which the whole agrestic population of the lower and central districts of the country between the Ganges and the Jumna were subjected, the painful inability of Government or the European community to afford relief commensurate with the necessity for it, and the striking contrast presented by those districts for which canal irrigation had been previously provided, were circumstances too remarkable to be passed lightly over. Colonel Cautley's views on the subject were accordingly submitted to Lord Auckland, then Governor-General of India, with the recommendation that such expenditure should be authorised as might be found necessary in examining the difficult country through which the first part of the suggested canal would be carried. His lordship gave immediate sanction to the inquiry, and to his honour be it said, he manifested during the whole course of his administration, both privately and officially, the deepest interest in the project.

A minute and careful examination of the country between Hurdwar, the proposed head of the canal, and Rúrkhí, the point at which it would enter upon the high land bounding the valley of the Ganges, was now instituted, and the results are

embodied in Colonel Cautley's first Report on the Ganges Canal, which bears date the 12th May 1840.

Of this report I need say no more than that it established, in the most satisfactory manner, the practicability of the project, showing that there were no difficulties in the line of the low country from Hurdwar to Rúrkhí, which might not be overcome at a reasonable cost.

This first project, however, was limited to constructing a canal of such dimensions only as would secure a remunerating return on the expense incurred. The practicability of passing the valley of the Ganges having been proved, it was left to the Governments in India and England to determine the scale on which the works should ultimately be carried out. It is scarcely necessary to add, that the appropriation of the entire visible stream at Hurdwar, so as to increase the discharge of the canal from 1000 to nearly 7000 cubic feet per second, was earnestly recommended by Colonel Cautley.

In 1840–41, the report came under the consideration of the Court of Directors, who decided, wisely and worthily, that the projected canal should be constructed on such a scale as would admit of irrigation being supplied to the whole of the country lying between the rivers Ganges, Hindun, and Jumna, forming the principal part of the North-Western Provinces.

The Court of Directors being desirous, however, that a work of such magnitude and cost as the proposed canal should undergo the most careful examination and discussion, directed a committee of experienced engineer officers to be associated with Colonel Cautley in reporting on the best method of carrying their enlarged views into effect. This committee, which consisted of Colonel F. Abbot, C.B., and Major Baker of the Engineers, with Colonel P. T. Cautley, submitted their report in February 1842, and recommended that the canal should be constructed of such dimensions as would admit of its discharge being 6750 cubic feet per second, which supply was considered sufficient for the irrigation of the whole Doab.

On receipt of the committee's report, Government gave orders for the vigorous prosecution of the work; but before the neces-

sary arrangements could be matured, Lord Auckland's administration ceased, and Lord Ellenborough's began.

With this event commences a dreary and distasteful chapter in the history of the great canal. I allude to it at all with reluctance, as the details are such as can be regarded by all interested in the success of this great work, only with feelings of profound regret. No good end can be served by dwelling now on such details; and it is, therefore, sufficient to state, that assistance in qualified officers was withheld from April 1842 to February 1843, the works being carried on by the aid of a single uncovenanted assistant during that interval.

It was not until July 1843 that Colonel Cautley was relieved from the executive duties of the Ganges, Eastern Jumna, and Dhún Canals, and thereby enabled to turn his undivided attention towards the completion of the survey, and of the designs for the first of these works.

Meanwhile, however, the original project had been totally altered. A minute of the Governor-General directed that the Ganges Canal should be primarily a canal of navigation, not of irrigation; and that only such portion of the water as was not required for the former object should be applied to the latter. This decision was opposed to the views of every man who knew anything either of the true necessities of the country, or of the nature of the works projected; and to carry it into effect to its full extent would have been to sacrifice all, or nearly all, the benefits which the original design secured to the agriculture of the country, and to give in return what at best, in this railway epoch, can be considered as only a second-rate means of transport to its commerce.

During the cold weather of 1843–44, the survey of the line was resumed, and carried on to the terminus at Allahabad. On the results of this survey three different projects were based, securing the benefits of irrigation to the country, so far as was consistent with the main object prescribed; and it was left to Government to decide which of the three should be adopted.

Before any resolution could be formed, Lord Ellenborough's administration ceased; and the final decision of the question devolved on Lord Hardinge. During the course of the year

1845, Colonel Cautley returned to England, and was succeeded in the directorship of the Ganges Canal by Major Baker.

The supposed effect of the existing canals of the Jumna, in diminishing the salubrity of the districts through which they were carried, created a new obstacle to the progress of the Ganges Canal; and a committee was appointed to investigate the question as thoroughly as possible. This committee, consisting nominally of three, but actually of two officers (Major Baker and Dr Dempster of the Horse Artillery), commenced their labours in November 1845, but were interrupted by a summons to do military duty with the army of the Sutlej. Their researches were not resumed until November 1846; and their Report, an invaluable storehouse of facts, was submitted to Lord Hardinge at Roorkhí in March 1847. To this Report I need not refer here, as it must come under notice hereafter, when the results of Italian experience in the sanitary relations of irrigation are discussed in the second volume of the present work.

The effect of the committee's report was, however, very satisfactory. Lord Hardinge recommended the vigorous prosecution of the work. Arrangements were made for the supply of ample means, both in men and money; and at length, in 1848, twelve years after the first line of levels for the project had been taken, the Ganges Canal may be said to have been fairly commenced, on a scale commensurate with its importance, and on the plan which its projector advocated from the first, and amidst all opposing influences never ceased to advocate—that, namely, of a canal, primarily of irrigation, but provided with all works necessary for purposes of navigation. This long period of delay has not been all evil: no project has ever undergone more searching investigation, or more minute discussion, than that of Colonel Cautley for the Ganges Canal. Every paper connected with it has been printed, and submitted to professional and general criticism; errors of detail have been brought forward, but none that affect the stability of the project; and Government may carry it forward to completion with the satisfactory assurance that every part of it has been so proved and tested as to justify confidence in the soundness of the whole.

I will now endeavour to give an outline sketch of the canal, as in progress of execution.

At about two and a half miles north of Hurdwar, a branch leaves the right bank of the river Ganges, and, flowing past the sacred ghats, and under the picturesque buildings of the town, follows a course, generally parallel to that of the parent stream, which it rejoins at a point thirty or forty miles to the southward.

Possession has been taken of the upper portion of this branch for the head of the canal, and through it the supply of 6750 cubic feet per second will be brought to Myapúr, a point about one and a half miles south of Hurdwar, where the artificial channel commences.

The first masonry works are constructed at Myapúr. They consist, first, of a dam across the branch of the Ganges, having thirty-eight openings of ten feet each, fitted with gates or sluices, and flank overfalls, by which a clear water-way of 517 feet is secured for the passage of floods from the Ganges during the rainy season; and, second, of a regulating bridge across the canal bed, having 200 feet of water-way in ten openings of twenty feet each, fitted with all the machinery necessary for regulating the admission of water into the canal. The dam and bridge are connected by a long line of masonry revetment; and, on the opposite bank, the similar line of revetment, with bathing-ghats, &c., complete the works at the head of the artificial channel.

Considerable anxiety has naturally been manifested by the brahmins of Hurdwar, lest these works, and especially the excavations in the bed of the river opposite the Pyrie, or sacred bathing-ghat, should interfere with their functions, or destroy the character of Hurdwar as a place of pilgrimage. For such feelings the utmost consideration has, of course, been shown; and the arrangements for clearing the bed of the river will be so made as that the facilities for bathing will be improved, and the risks of accidents which now exist removed.

I have before stated that the grand, indeed the only, obstacles to the construction of the canal are met with on the first twenty miles from the head, or between Hurdwar and Roorkhí. These difficulties arise from the course of the canal intersecting at right

angles the whole of the drainage of the sub-Himmalayas, of which the western valley of the Ganges is the receptacle.

This drainage, independently of numerous minor channels, which are unimportant, is collected into three great lines, being the valleys of the Puthri, the Ruthmú, and Solaní rivers, draining respectively six, eleven, and eight miles in length of the hill country. The Puthri drainage, being divided among a number of minor channels, is not difficult to control, but the Ruthmú and Solaní are impediments of the highest class.

The artificial channel of the canal leaves Myapúr with a transverse section, having a constant width at bottom of 140 feet, and a variable width at top, dependent on the depth of excavation, but which may be stated generally to be about 200 feet. The depth of water provided for is 10 feet, and the slope of the bed about 18 inches per mile. After pursuing its course for about six and a half miles, and crossing several lines of drainage, which are disposed of either by dams or inlets and outlets, the canal is lowered into the valley of the Puthri river by means of the Bahadurabad Falls, similar to, although on a very much larger scale than, those of the Eastern Jumna Canal.

For purposes of navigation, whether by rafts or boats, a side-channel furnished with locks, leaving the main canal about three quarters of a mile above, and rejoining it about one quarter of a mile below the falls, has been provided.

After leaving the Bahadurabad Falls, the canal traverses for about five miles the low land intersected by the Puthri river and its numerous tributaries. The former is passed by a dam having ten openings of 10 feet each, and flank overfalls, leaving a clear water-way of 130 feet; and the latter, being of minor importance, by inlets on one bank, and corresponding outlets on the other.

At the termination of the Puthri Valley, the Dhunoura Falls, similar in all respects to those at Bahadurabad, lower the canal to the level of the Ruthmú river, one of the two great obstacles to its progress.

In the original design this river was passed by a dam, having forty openings of 10 feet each, fitted with gates for retaining the canal supply; but the great floods of the year 1844 rendered an extension of the work necessary. As now projected, the Ruthmú

dam will have forty central openings of 10 feet each, and two side openings of 100 feet each, with flank overfalls; so that the clear water-way above the pier-heads will be very nearly 800 feet. A regulating bridge, similar to that at Myapúr, will be built across the canal, with the view of excluding the waters of the Ruthmú during floods.*

The valleys of the Ruthmú and Solaní rivers are separated by a high ridge of land about two miles in breadth, through which the canal is carried with a maximum depth of digging of 37 feet. At the village of Bajuheri it enters the valley of the Solaní, which at this point is 11,680 feet, or nearly two and a quarter miles in width. The level of the canal-bed here begins at once to rise above the surface of the country, and the great work of embanking the channel, or forming the earthen aqueduct, commences.

This work, by which the canal is brought through the valley to the Solaní river, will consist of an earthen embankment or platform, raised to an average height of about 16½ feet above the country, having a base of about 350 feet in width, and a breadth at top of about 290 feet. On this platform the banks of the canal will be formed, 30 feet in width at top, and 12 feet in depth. These banks will be protected from the action of the water by lines of masonry retaining-walls formed in steps extending along their entire length, or for nearly two and a quarter miles north of the Solaní.

The river itself is crossed by a masonry aqueduct, which will be not merely the largest work of the kind in India, but one of the most remarkable for its dimensions in the world.

The total length of the Solaní aqueduct is 920 feet. Its clear water-way is 750 feet, in fifteen arches of 50 feet span each. The breadth of each arch is 192 feet. Its thickness is 5 feet: its form is that of a segment of a circle, with a rise of 8 feet. The piers rest upon blocks of masonry, sunk 20 feet deep in the bed of the river, and being cubes of 20 feet wide, pierced with four wells each, and undersunk in the manner practised by

* During the actual execution of the works, numerous modifications in detail have naturally been introduced. I do not advert to these here, as doing so would involve technical discussion foreign to my present object.

natives of India in constructing their wells. These foundations, throughout the whole structure, are secured by every device that knowledge or experience could suggest; and the quantity of masonry sunk beneath the surface will be scarcely less than that visible above it. The piers are 10 feet thick at the springing of the arches, and 12½ feet in height. The total height of the structure above the valley of the river will be 38 feet. It will not, therefore, be an imposing work when viewed from below, in consequence of this deficiency of elevation; but when viewed from above, and when its immense breadth is observed, with its line of masonry channel—which, when completed both north and south of the river, will be nearly three miles in length—the effect must be most striking.

The water-way of the canal is formed in two separate channels, each 85 feet in width. The side-walls are 8 feet thick and 12 feet deep, the expected depth of water being 10 feet. Various buildings are provided at the flanks of the aqueduct, and many minor arrangements are made which it would be wearisome to describe here. A continuation of the earthen aqueduct, about three-quarters of a mile in length, connects the masonry work with the high bank at Roorkhí, and brings the canal to the termination of the difficult portion of its course. Such details as these convey, I am well aware, but a very imperfect idea of the work. They are, however, our only substitutes for plans or other graphic representations; and I must hope for their being intelligible enough to give some conception of the magnitude of the structure.

The total cost of the canal from Hurdwar to Roorkhí is estimated at nearly £300,000, of which sum the aqueduct will absorb a little more than one-half, or about £158,000.

The heavy cost, and the admitted difficulties in constructing so great a work as the Solaní aqueduct, led to much discussion as to the practicability of avoiding it by carrying the canal on a circuitous route, and crossing the river at a higher point in its course by means of a dam. This question was carefully investigated by the special committee, with this result, that while the circuitous route was perfectly practicable, it was exposed to many objections; and that, although it might lead to a saving of expense in the

first instance, it would inevitably entail much greater ultimate outlay in maintenance than if the direct course were adopted. The opinion of the committee was therefore unanimously in favour of the aqueduct, and Government decided the point in accordance with their views.

From Roorkhí the canal continues its course, without meeting with obstacles of any kind, through the centre and along the most favourable levels of the country between the rivers Ganges and Jumna, throwing off branches which rival in dimensions the largest of the existing canals. The first of these, the Futtehghur branch, which leaves the canal at about 50 miles from the head, is 150 miles in length, and will have a discharge equal to 1240 cubic feet per second. The second, or Bolundshuhur branch, has a length of 70 miles, and a discharge of 520 cubic feet per second. The third, or Etawah branch, is 172 miles long, with a discharge of 1336 cubic feet per second. The fourth, or Cawnpúr branch, has a length of 43½ miles, and a capacity of section equal to a discharge of 635 feet per second. This branch forms, according to the recommendation of the special committee, the connecting link for navigation between the Ganges and the canal; and the construction of a series of locks at Cawnpúr will admit of an easy passage for boats from the one line to the other. The main line of canal from Cawnpúr to Allahabad, a distance of 173 miles, has a supply for purposes of irrigation, amounting to 1076 cubic feet per second. The preceding distribution of the supply to the branches, and corresponding allowance for the intervening portions of the main line, leave available for purposes of navigation exclusively a supply equal to 250 cubic feet per second. In the event of the navigable terminus for river traffic being established at Cawnpúr, this supply would be reserved for the branch to that place; if Allahabad is preferred—which, however, is not probable—the increased supply must be appropriated to the main line.

The total length of the Ganges Canal and its branches is as follows:—

Main line from Hurdwar to Allahabad, . . .	453 miles.
Futtehghur Branch, ...	160
Bolundshuhur ditto, ...	70
Etawah ditto, ...	172
Cawnpúr ditto, ...	43½
Total,	898½

As each of the branches, as well as the main line, will be adopted for internal navigation, the commerce of the region traversed by them will participate, with its agriculture, in the benefits to be derived from the canal. For purposes of cross communication, bridges will be provided at every two or three miles. All the various works required for the regulation of the supply, for the convenience of the establishment, for mills, &c., will be constructed wherever required. Plantations will be formed within the canal limits on each bank. Orchards of grafted mango-trees, similar to those so successfully established on the Eastern Jumna canal, are estimated for. The transverse section of the canal is gradually diminished, as each branch draws off its proportion of the supply from the main line. From the head to the Futtehghur branch, the bottom width continues, as before mentioned, to be 140 feet, and the depth 10 feet. Between the Futtehghur and Bolundshuhur branches, the bottom width is reduced to 130 feet, and the depth to 9 feet. From the Bolundshuhur branch head, the width becomes 108 feet, and the depth 9 feet. After the departure of the Etawah branch, the bottom width is 90 feet, and the depth 7½ feet. At the 250th mile, the section is again reduced to 80 feet in width, and 7 feet in depth. From the head of the Cawnpúr branch, the section is 75 feet in width at bottom, and 6 feet deep; and at the Allahabad terminus, the width will be 25 feet at bottom, 37 feet at top, and 4 feet in depth. Throughout the canal, the side slopes will have bases equal to one and a half their heights, and the longitudinal slope of the bed will vary from 15 to 12 inches per mile.

The distribution of water for purposes of irrigation will be effected exclusively by means of principal water-courses, under the superintendence of government officers. No private water-courses will be permitted, either from the main canal or its branches. The full benefits of the most economical and most salubrious method of irrigation will thus be secured to the country from the commencement.

The maximum cost of the canal, supposing that government constructs, at its own expense, not only the main line and branches, but also the primary channels of distribution, or Rajbuhas, is estimated at a million and a half sterling.

Having thus given an outline of the works, and stated their probable cost, I have now to exhibit, as briefly as possible, the benefit which will be secured to the government and the community, as the return for so large an expenditure.

The first point to determine is the extent to which the Doab will be irrigated by the canal and its branches. The districts to which the influence of the Ganges canal and its branches will extend, together with details of their assessed areas, are given below. From the areas of Saharunpúr, Muzuffernuggur, and Meerut, I have deducted the portions already provided with means of irrigation from the Eastern Jumna canal. I have taken from the statistical tables only the cultivated and culturable areas, because it is for these alone that irrigation has to be provided.

	Cultivated area in acres.	Culturable area in acres.
1. Saharunpúr,	501,606	392,508
2. Muzuffernuggur,	505,830	236,216
3. Meerut,	972,213	476,427
4. Bolundshuhur,	657,071	359,713
5. Allyghur,	901,405	129,710
6. Muttra,	676,323	106,129
7. Furruckabad,	652,075	305,095
8. Mynpúri,	613,338	182,000
9. Etawah,	477,901	139,850
10. Cawnpúr,	781,173	163,565
11. Futtehpúr,	518,812	123,985
12. Allahabad,	997,508	231,597
Totals,	8,255,255	2,846,793

The total area, cultivated and culturable, of the above twelve districts, is therefore 11,102,048 acres.

Now, supposing that the full supply of the canal, being 6750 cubic feet per second is rendered available for irrigation—as ultimately we have no doubt it will be—we know, from experience on the canals of the Jumna, that each cubic foot of this discharge is sufficient for the irrigation during the year of 218 acres. The total area which would be actually watered during the year would consequently amount to $6,750 \times 218 = 1,471,500$ acres; or, for facility of calculation, say 1,500,000 acres.

Assuming, as a standard of comparison for the whole of the Doab, the best irrigated districts on the Eastern Jumna canal—namely, the western portion of Meerut—we find, by reference

to the statistical table previously given for the above-mentioned canal, that irrigating villages actually water one-third of their total areas; consequently the supply of the Ganges canal would furnish abundant irrigation for an area of $1,500,000 \times 3 = 4,500,000$ acres.

In districts benefiting by canal irrigation, it is found that for such localities as, from position, difficulties of level, or other causes, cannot be provided with water, irrigation from wells is extensively employed. From data given in the Special Committee's report, it would appear that, in the best irrigated district on the Western Jumna canal, the proportion of canal to well irrigation is as five to one. Assuming this for the Doab, we should have an area, irrigated from wells, amounting to 900,000 acres.

The total area, for which irrigation would be provided, would accordingly amount to 5,400,000 acres. But the whole irrigable area of the Doab is, as formerly shown, 11,102,048 acres. This tract of country would, therefore, be irrigated to the extent of very nearly one-half its surface; a proportion equal to that of the best district west, and nearly double that of the best district east, of the Jumna. In making this comparison, it should not be overlooked that the best districts on existing canals have been selected as standards for the whole Doab—a measure which tends to give a more limited range to the influence of the Ganges canal than would have been the case had inferior tracts been selected. But I am anxious to avoid all appearance of exaggeration in estimating the benefits to be anticipated from this great work, and, as a rule, will select such data as give minimum results, believing these to be abundantly convincing.

The results just given are not quite so favourable as those shown either in the Special Committee's report, or in Colonel Cautley's second report; but I believe them to be as just, and as nearly correct, as it is practicable to make them. An error, unimportant as it affects the project generally, but leading to an exaggerated estimate of the irrigating capabilities of the canal, crept into Colonel Cautley's first report, and vitiated the conclusions on this branch of the question therein arrived at. The error was, however, fortunately an isolated one, and, although

magnified at the time of its discovery for special purposes, was in reality of very little consequence.

The direct pecuniary returns from the canal may be estimated as follows:—

Water rent, per annum,	£147,150
Mills, do.,	10,000
Transit duties, do.,	6,000
Sundries, canal produce, &c., do.,	700
Total,	£163,850

The indirect return from increase of land revenue, which, from the analogous case of existing canals, we are entitled to anticipate, may be estimated from data furnished by the statistical tables formerly given. Assuming for the Doab generally the average results on the Eastern Jumna canal, we find that the land revenue in districts irrigated by canals exceeds that in districts not so irrigated, by £45 per square mile. Now, the area which will come under the influence of the Ganges canal amounts to 4,500,000 acres, or very nearly 5312 square miles. The increase of land revenue would accordingly be as follows:—

5312 square miles, at £45 per mile, ... £239,040

The total pecuniary returns, direct and indirect, would therefore be nearly £400,000 per annum.

From experience on existing canals, and assuming as the standard of comparison the Eastern Jumna canal, the most expensive of the whole, the annual outlay for the ordinary repairs, and the regular establishments of the Ganges canal, is estimated at very nearly £40,000. For increased expenses in the Civil departments, a farther sum of £10,000 per annum may be allowed.

The net revenue from the canal, when in full operation, would therefore amount to £350,000 per annum, which gives a return on the invested capital (amounting to £1,500,000) of 23⅓ per cent. This very favourable result is by no means an exaggerated one. It is less by 13⅓ per cent than the actual returns on the Western Jumna canal, and within ⅔ per cent of those of the Eastern Jumna canal.

I have already shown that neither of these works has yet attained its maximum; and, even with all the improvements

that can be effected in them, they must still continue inferior to the Ganges canal in the arrangements for distributing and economising their respective supplies of water. Such considerations, therefore, warrant us in considering the results just given as moderate. My personal conviction is, that when this great canal has attained its highest state of development, it will secure to the state a total revenue of little less than half a million sterling per annum.

The benefits which will be secured to the community by the execution of the canal are in nowise inferior to those derived by the government. In exemplification of the former, I must now give a few details; and, first, of the value of agricultural produce, which will be placed beyond all risk of injury from inadequate supplies, or the total failure of rain. From tables showing the proportions of the different kinds of crops cultivated on existing canals, I have formed the estimate given below:—

	Crops of the Rainy Season.	
Proportion	of sugar, indigo, &c., . . .	$\frac{1}{6}$th of the whole.
...	of cotton, ...	$\frac{1}{12}$th ...
...	of rice and sundries, . . .	$\frac{3}{12}$ths ...
	Crops of the Cold Season.	
...	of wheat, barley, &c., . .	$\frac{3}{6}$ths ...

Assuming these proportions as approximate for the whole Doab, we have the following results, the rates per acre being the same as have been employed in the corresponding estimates for the Eastern and Western Jumna canals.

CALCULATION OF THE GROSS VALUE OF CROPS WHICH WILL BE SECURED FROM INJURY IN FAMINE SEASONS BY THE GRAND GANGES CANAL.

	Crops of the Rainy Season.	
250,000	acres of sugar and indigo, at £8 per acre, . .	£2,000,000
125,000	... of cotton, at £4, 16s. per acre, . . .	600,000
375,000	... of rice and sundries, at £3, 16s. 6d. per acre, .	1,434,375
	Crops of the Cold Season.	
750,000	... of wheat, barley, &c., at £4, 16s. per acre, .	3,618,750
	Total, .	£7,653,125

Of this sum (upwards of $7\frac{1}{2}$ millions sterling per annum) about one-tenth will return to government in the form of land and water rent, while the remainder will be the property of the agricultural community. It is needless to dwell on the importance

of placing property, equal to between one-fifth and one-sixth of the value of the agricultural produce of the entire Presidency of Agra, beyond the influence of the seasons, and of insuring to the cultivators, under all circumstances, a certain return for their labour. The influence of the canal on the improvement of the Doab must necessarily be immense. This great tract will become the garden of the North-Western Provinces; and we shall hear no more of those devastating famines, which have hitherto swept across it, bringing physical wretchedness and moral degradation in their train.

In addition to the certainty of returns, the actual produce of irrigated land exceeds materially that of land unirrigated. From data collected during the progress of the revenue survey, it appears that the excess on irrigated over unirrigated land may be taken, for the cold-weather crops, as being about 550 lb. per acre for wheat, and about 730 lb. for barley. Assuming the average of these for the general excess, we have the following estimate of the increase of produce due to the existence of the canal. 750,000 acres under cold-weather crops, will amount,

At 640 lb. per acre, to . 480,000,000 lb., or 4,000,000 quarters.

The value of this increase, allowing the market rate to be only 3s. per quarter, would amount to £600,000 per annum.

Those are not data sufficient to enable me to estimate in detail the increase on the rain crops; but considering that this season, including as it does sugar, indigo, and cotton, is by far the most profitable to the cultivator, and that irrigation exercises an equally beneficial effect upon it as upon the produce of the cold season, we may with great safety conclude that the increase during the summer season will be at least equal to that during the latter. Hence the total increase of the value of the produce would amount to £1,200,000 per annum—a sum nearly equal to the total capital invested in the canal.

A farther source of benefit to the community will be found in the reduced cost of canal, as compared with well, irrigation. The average area irrigable by one masonry well is ten acres; and to bring under irrigation a tract of country equal to that which will be watered by the Ganges canal would consequently

require 150,000 wells. Estimating the cost of each of these at £20, the total capital required for their construction would amount to £3,000,000; being considerably more than twice the sum necessary for the Ganges canal, with all its works for supply and distribution of water. The above sum of three millions only provides the water: to distribute it, the labour of two able-bodied men and eight bullocks is required for each well, together with machinery for raising the supply to the surface. To provide the means of working 150,000 wells would cost £900,000; and allowing £100,000 more for machinery, it appears that, to provide well irrigation for 1,500,000 acres, would require a capital of £4,000,000.

The annual expenses for irrigation may be estimated as follows:

300,000 men, at £3 per annum, ...	£900,000
1,200,000 bullocks, at £1⅕ per annum, ...	1,440,000
10 per cent on total capital, ...	400,000
Total annual expense of well irrigation for 1,500,000 acres,	£2,740,000

Let us now contrast the above with the cost of canal irrigation. I will suppose that, as on existing canals, the cultivators bear all expenses of constructing and maintaining the principal water-courses. I formerly stated, while discussing the distribution system of the Eastern Jumna canal, that the original cost of these works amounted to 5s., and the annual expenses to 7d., per acre. The capital required would consequently be £375,000. The annual expenses would be as follows:—

Government water-rent at 2s. per acre, ...	£150,000
Water-course repairs, at 7d., ...	43,750
Labour, at £2, 8s. per annum, ...	72,000
10 per cent interest on capital, ...	37,500
Total annual expense of canal irrigation for 1,500,000 acres,	£203,250

By comparing these calculations, it will be apparent that well irrigation is upwards of thirteen times more expensive than irrigation from canals; and, as one or other of these methods must be had recourse to, if cultivation is to be secured from the effects of drought, there can be very little question as to which is to be preferred. The saving to the agricultural community, from having means of canal irrigation at its command, will be nearly 2½ millions sterling per annum. I have considered it necessary

to enter in some little detail on this point, because a mistaken idea has been entertained that, if the funds appropriated to the Ganges canal had been applied to the construction of wells, the results would have been equally, if not more, favourable to the cultivators. These, however, on existing canals, give the best possible proof of their own views on the question, by abandoning at once their wells, and incurring willingly all the expenses required for providing their lands with water from the canals.

I have not the means of showing in any numerical form the advantages which would result to the commercial community from the easy transport furnished by the main canal and its branches. When, however, it is borne in mind that the canal runs centrically through the Doab, connecting all its important marts; that its branches diverge to the right and left of the centre line; and that, by the main line with its great branches, an internal navigation, having connecting points with the two chief rivers of the Doab, nearly nine hundred miles in length, will be provided, it is certain that great facilities for commerce must be secured. The true commercial way is, of course, the railroad; but, in subordination to this (and a navigable canal of irrigation can never be other than a mere auxiliary to the rail), the Ganges canal will perform an important part in stimulating the commercial progress of the districts through which it will be carried.

I have now, I believe, sufficiently illustrated the benefits which will be secured to the state and the community from the execution of this grand canal. It has been shown that it will add to the revenue of the government the sum of £350,000 per annum; that it will protect from the risk of famine a tract of country, containing upwards of 11,000,000 acres, inhabited by nearly 6½ millions of souls, and paying to the state an annual land-revenue of nearly £1,800,000. It has further been shown that, in the event of a failure of the ordinary rains, agricultural property to the value of 7½ millions sterling would be secured to the community; that an increase in the produce of the land, valued at £1,200,000 per annum, would be obtained; and that, as compared with the only other available method of irrigation, a saving of expense to the amount of 2½ millions annually would

be effected. In view of results such as these, and feeling that the hope of their realisation is warranted by all past experience on existing canals, it is natural that the advocacy of a project so important should be earnestly expressed.

It only remains for me now to take into consideration the objections to the Ganges canal, which from time to time have been advanced by parties unfavourable to the work.

The first, and by far the most important, of these is the effect which will be produced on the navigation of the river Ganges, by the abstraction at Hurdwar of so large a portion of the stream as 6750 out of 8000 cubic feet per second.

To guide us in the discussion of this question, we have the results of an experience of the canals of the Jumna, extending over more than twenty-five years; and, as the relations of the rivers Jumna and Ganges to their respective canals are strictly analogous, we may, with confidence, predicate of the one whatever has been established by observation of the other. The two rivers differ only in magnitude. The physical circumstances regulating their respective supplies are strictly similar. The geological structure of their beds is the same. They originate in the same snowy range, and have their volumes affected to similar extents, and at the same times, by the ordinary influence of the season. No firmer basis for inductions regarding the results of the Ganges canal could therefore be desired, than the facts furnished by our experience of the canals of the Jumna. To the influence of these latter on the volume of their supplying river, I must therefore direct attention in the first place.

To all familiar with the phenomena of the Himmalayan rivers, it is well known that, independently of the increase of volume due to the periodic rains, which in ordinary seasons is experienced from July till November, the melting of the snow, during the months of April, May, and June, exercises a most perceptible influence on their supply. On the canals of the Jumna, all anxiety regarding the supply ceases in April, when the river begins to rise. This rise continues to increase steadily until the rainy season commences, when the increase of supply is so great that the abstraction of the water required for the canals produces no perceptible effect on the river. The whole of

the canal "bunds" are then swept away; and the great object of the executive officers is to keep the flood waters as much as possible to the bed of the stream.

The effect of the canals on the navigation of the Jumna, whatever that effect may be, is therefore restricted to four months out of twelve, or from December to March inclusive.

During these four months it is occasionally necessary to abstract the entire visible stream for the supply of the canals; and, for eight or ten miles below the bunds, or embankments employed for the purpose, the bed is dry. Beyond this distance water appears; and, by the time the river has reached the latitude of Saharunpúr, it has become a deep unfordable stream, with a considerable velocity of current.

The explanation of this singular result, observed in greater or less degree in all the streams which traverse the tract of country under the Siwalic Hills, both east and west of the Ganges, is not difficult.* From sections exposed by wells sunk in the vicinity of the Jumna, it is evident that the bed of the river is composed of a porous, readily permeable stratum of shingle, resting upon clay, or clay sand, which is comparatively impervious. The upper or shingle stratum is thoroughly saturated with water, to a depth which, from sections we have observed, may be estimated at from 60 to 80 feet. The slope of the bed for the first ten miles from the lower hills is excessive, and there is consequently a considerable under-current through the shingle bed. The volume of the river may therefore be regarded as consisting of two separate parts: 1st, the visible stream over the shingle bed; and, 2d, the invisible, or under stream through the shingle bed. The canal bunds affect only the former; and it is the latter which makes its appearance when, at the lower levels of the river's course, the substratum of clay outcrops, and the porous shingle bed terminates. The under-current is thus thrown to the surface, and constitutes the main body of the river; and, with the additions it receives from affluents, is the volume available for navigation during the months of minimum supply.

Data are available from which a fair approximate estimate may be formed of the amount of this supply. The discharge of

* It will be remembered that I drew attention to similar phenomena on the rivers of Northern Italy, in the body of this work, p. 172.

the Jumna at the canal heads, when measured in February 1842, was found to amount to 3489 cubic feet per second.

The maximum discharge of the canals was at the same time ascertained to be 2815 cubic feet per second; but, as the supply of the Eastern Jumna canal has of late years been somewhat increased, I assume the maximum canal discharge to be 3000 cubic feet per second. Until the river therefore falls to this extent, it is not necessary to close the bunds and to abstract its whole supply.

The Jumna, when it was measured at Agra by Colonel Cautley, during its period of minimum discharge, and when the canals were in full operation, was found to contain 2061 cubic feet per second, of which 200 cubic feet were derived from the Hindun river, the solitary affluent of the Jumna between the lower hills and Agra, which carries a perennial supply. Hence there remain at Agra 1861 cubic feet per second, as the product of percolation through the shingle bed of the stream, escape water from the canals, and drainage from lands under irrigation. That this latter item is not altogether unimportant, may be inferred from the fact that, owing solely to the sinking of the canal water into the ground, the surface-level of the wells in many parts of the Western Jumna Canals has been raised no less than 60 feet.

Now, with the supply above specified, of 2061 cubic feet per second, it is an unquestionable fact that the Jumna continues to be a line of commercial traffic of the highest importance and utility. It is navigable for eight months of the year with facility for boats ranging from 18 to 36 tons burthen; during the remaining four months it is still navigable, but with difficulties due, not to any want of water, but to the faulty distribution of it in certain spots along the river's course. That the removal of these obstacles, by the application of the skill and funds at the command of government, would materially facilitate the navigation, is undeniable. The true state of the case is, that nearly the whole commerce of which the Jumna is the river-way is carried on during those months of the year when the influence of the rains, or of the melting of the snows in the Himmalayas, is felt; and that the practical inconvenience experienced during the months of minimum supply has not been such as to cause any injury to the commerce of the country, or to attract the attention of government in earnest to the subject. No one,

indeed, can see the crowd of boats moored off Agra at nearly all seasons, and yet have any serious misgivings as to the influence of the canals on the navigation of the river.

The general conclusion, therefore, at which we arrive is, that after the Jumna has received the very worst treatment possible; after its whole visible stream at its debouche from the hills has been abstracted for purposes of irrigation; after the larger proportion of the water thus drawn off has been thrown on a tract of country, draining into the valley of the Sutlej, and thus lost to the Jumna; while no efforts, worthy of being mentioned, have been made to improve its capabilities for navigation; and while its volume is increased by but a solitary and insignificant affluent, the river still maintains its character as a navigable line of admitted value, as high as Agra, or Muttra, during the year, and even to Delhi during, and for some time after, the rainy season. If we are able to show that in every respect the circumstances of the Ganges will be more favourable than those of the Jumna now are, it may fairly, I think, be concluded that the execution of the Ganges canal will not be found to affect prejudicially the navigation of the river below that point at which a provision is made for such a contingency.

Bearing the preceding statements in mind, let us now, therefore, direct our attention to the Ganges.

The proportion of the supply of the Jumna due to percolation has been stated at 1861 cubic feet per second. On the Ganges, supposing the entire visible stream at Hurdwar to be abstracted, and neglecting for the present all increase of volume from affluents, the proportion is determined as below—

$$3489 : 1861 : 8000 : 4267.$$

Or, to express this result in words, the Ganges at a point in its course, corresponding to the position of Agra on the Jumna, would have, from percolation, a discharge equal to 4267 cubic feet per second, being 778 cubic feet more than the total measured discharge of the Jumna in the cold season, before any of its water has been drawn off for the canals. The position of Futteyghur on the Ganges corresponds very closely with that of Agra on the Jumna, and to the condition of the river at that place the above statement is applicable.

I have supposed the whole visible stream at Hurdwar to be

abstracted; but it is not intended that it should be so. The estimated discharge of the Ganges canal being 6750 cubic feet per second, the surplus, amounting to 1250 cubic feet, would consequently be added to the under-current, raising the discharge at Futteyghur to 5517 cubic feet per second.

The tributaries of the Ganges between Hurdwar and Futteyghur or Cawnpúr, the Gangetic terminus of the canal, are numerous, and some of them important. The following give a perennial supply to the river:—

The Bhât Nudi, and the Turai (*marshy*) tracts of the Gangetic valley.	The Ramgunga.
The East Kali Nudi.	The Yar Wúffadar.
	The Isun.

Measurements of the actual discharges of these streams have not been made, except in the case of the Ramgunga, which, immediately under the hills, was found to have a discharge of 602 cubic feet per second. Its volume is described by Lieut. Jones, of the Engineers, as rapidly increasing below the point at which his measurements were made. Two tributaries to the stream were measured, and their united volume was found to be 567 cubic feet. Other tributaries are mentioned as affording a perennial supply, but they were not measured. It appears therefore probable that the Rumgunga alone increases the supply of the Ganges by about 1500 cubic feet per second; and supposing that the total volume of the other tributaries amounts only to 500 cubic feet—a very low estimate—we find the discharge of the Ganges at Futteyghur, or Cawnpúr, to be 7517 per second.

It must farther be remembered that the whole of the water taken off at Hurdwar will not be lost to the Ganges; a portion will be returned by the canal escapes, mills, &c., and another portion by the percolation through the soil. These I do not attempt to estimate numerically; but the latter will certainly exceed materially that returning to the Jumna from the canals of that river.

I wish it to be understood that I am far from desiring to insist on the rigid accuracy of the preceding details. I give them as approximations founded on the best available data, and as much preferable to mere statements of opinion.

Making an ample allowance for the possible diminution of the supply from the tributaries on the left bank of the Ganges by the execution of future projects for the extension of irrigation on

the left bank of the river, we still find that the discharge of the Ganges at Futteyghur will be nearly three times that of the Jumna at Agra. Now, although the bed of the Ganges is throughout much wider than that of the Jumna, yet the portions occupied as channels for the streams during the cold season in both rivers bear but a small ratio to the total widths. These cold-weather channels, formed as they are in sandy beds, are proportional in extent to the volumes of water they have to discharge, and they readily accommodate themselves to these. The capabilities of the two rivers for navigation would therefore be in the ratio of the quantities of water discharged by them, supposing them to continue in their natural state; and hence it may be inferred that the Ganges at Futteyghur will, after the execution of the Ganges canal, be navigable with considerably greater facility than the Jumna now is at Agra. But at Agra, as was before shown, the Jumna is a navigable stream of great importance and value; and therefore I conclude that at Futteyghur the Ganges will be available for traffic to nearly the same extent that it now is.

From Futteyghur, or Cawnpúr, to Súkertal, the most northerly point to which boats now reach, the navigation of the Ganges will probably be injured for four months out of twelve. Even at present the navigation between these points during the cold season is very precarious, and the extent of traffic very limited. It must, therefore, be expected that the withdrawal of seven-eighths of the visible stream at Hurdwar will add to the existing difficulties; and should experience establish this, a fair claim will exist on the government to devote some portion of the resources which the canal will furnish to the improvement of the river as a navigable line.

It being admitted that, north of Cawnpúr, the river will suffer, in the first instance, from the withdrawal of the canal supply, it must now be stated that, so far as the traffic of the right bank is concerned, the canal itself will furnish a line of navigation much superior in facility of transit, safety, and economy to that now afforded by the river. In addition to the main line from Cawnpúr to Hurdwar, the net-work of internal navigation, formed by the large branches of the canal, will supply to the import and export trade of the Doab accommodation far exceeding that now

given by the river; and should a navigable line be established to the Jumna, near Calpi, or some other favourable point, there can be no reasonable doubt that the Ganges canal will prove a boon of the highest order to the commerce, as well as to the agriculture of the country.

The objection to the canal on the score of the injury it will inflict on the navigation of the Ganges, therefore, resolves itself into the fact, that for one-third of the year the inhabitants of the villages (for there are no large towns or marts) on the left bank of the river, from Futteyghur to Gurmuktesur, a distance of about a hundred and fifty miles, will have their present imperfect means of transport rendered somewhat more imperfect. The ultimate result, however, even here, may be beneficial, should attention be directed to the removal of those obstacles which impede the navigation. On the Ganges very little has yet been done to regulate the supply of water, or to improve the channel during the cold season. It is not want of water that is complained of. There is abundant volume for the supply of a navigable stream; what is required is, to prevent this water spreading into wide shallows, and to restrict it to a bed of such dimensions as that sufficient depth and velocity of current may be secured. It is scarcely to be supposed that, in such a case, the practical difficulties would be found to be beyond the skill and the means at the command of the Government.

In carrying into effect any great public work, it is always expected that some existing interests will suffer. I have now shown that, in the case of the Ganges canal, this injury is the least possible, viewing matters at their worst; while, looking on them at their best, the anticipated injury may be the source of great ultimate benefit. The question is one of comparison; and when the advantages and disadvantages of the canal are fully contrasted, there can be but little, if any, hesitation in assigning an immense superiority to the former.

In a case like the present, where the argument is of necessity analogical, authority may be quoted with effect; and when we find that all those officers who have devoted their professional lives to the study of Indian hydraulics, are unanimously in favour of the execution of the canal, we cannot but admit that Government has acted wisely and well in overruling the objections that

have been advanced. The opinions of Colonels Colvin, Abbott, and Cautley, of Major Baker, who have carefully examined the question in all its bearings, have been recorded in advocacy of the project. There is no difference of opinion as to the influence of the canal on the navigation of the Ganges below Cawnpúr. Above that point, the effect of the canal is variously estimated by different parties. What has already been stated will show that different estimates regarding this point are of very little importance.

The question has hitherto been regarded as between the river and the canal; but, to dispose of a second objection, I must as briefly as possible consider it as between the canal and the railway. The appropriation of resources to the construction of the canal, which for commercial purposes might have been so much better applied to promoting railways, has been condemned.

Had the alteration of the original design, directed by Lord Ellenborough, been carried into effect, and had the Ganges canal been made primarily a canal of navigation, the objection above stated would have been pertinent and irrefutable. To construct a canal for commercial purposes, when a railway is available, is wilfully to cast aside the improvements provided to our hands. It is to fall behind, not to keep pace with, the spirit of the times; to substitute for a first, a second rate means of commercial progress. But the Ganges canal is primarily an agricultural, not a commercial work; and, in its first capacity, no development of the railway system can in the slightest degree replace its functions or diminish its utility. The agriculture of the North-Western Provinces must continue to be dependent on irrigation, natural or artificial, however extensively the iron-ways may be spread over the land; and the agrestic population, the bulk of the community, can never derive from railways that immunity from famine which the canal is calculated to secure for them. It is not by pouring the superabundant produce of more favoured localities into these provinces that famine can be prevented. Even in the worst cases on record, there was no reason to suppose that food did not exist. It was the means of purchasing this food that were wanting, in consequence of the utter annihilation of the resources of the agricultural community. I may illustrate

this by an example. Our famines in India are analogous to that of Ireland: a failure of the periodic rains is to the inhabitants of that region what the potato disease was to the Irish; and as, in the latter case, an open seaboard and an unlimited freedom of importation would of themselves have done nothing to alleviate the distress experienced, so in the former the most perfect facility of transit would be found useless. In both instances, money has to be supplied in exchange for that labour which is usually devoted to tillage; and public works, in too many instances most expensive and unprofitable, have to be carried on with the resources of the state. For a government to undertake to find work and food for several millions of starving people is at all times an appalling, and never a perfectly successful task. It is to obviate the necessity for this, in the populous provinces of the Doab, that the grand canal is designed; and it will effect its object in the most natural and beneficial manner, by securing to the people the power of profitably employing their labour on their own lands, even should the rains from heaven fail them. In its peculiar and primary relations to agriculture, no railway can, therefore, ever become a substitute for the canal.

Navigation is a secondary object; and the proportion of the entire cost of the canal, which is applied to rendering it an easily navigable line, is very insignificant, not exceeding a twentieth part of the whole. I do not think, therefore, that to employ this small proportion of the estimated amount for commercial purposes can be deemed any misappropriation of our resources.

Navigable canals of irrigation and railways should never be exhibited as antagonistic works. They are not so in any way whatever. They occupy contiguous but independent provinces, linked together, however, in the most intimate relations of mutual support and aid. The one cannot attain its fullest development without the co-operation of the other; and although of the two the canal is certainly the more independent, yet its influence on the prosperity of the country would be greatly enhanced by the existence of its sister work.

To all interested in the progress of Indian railways the execu-

tion of the Ganges canal ought, therefore, to be an object of importance, since, as long as the staple products of the land continue at the mercy of the seasons, so long must the returns from the rail participate in the like insecurity. In extreme cases, there would be no produce to transport, no means to purchase the goods the rail might bring, and no passengers to carry ; and the income of the shareholders must of necessity cease for the time, to be recovered only after the long-felt effects of such devastating visitations had passed away. The community of interests, and the proper relative positions of the canal and the railway, may now, I hope, be understood, and the advocates of each may see that they may with propriety give hearty support to the other.

A third, and the last, objection which has been made to the canal is based on the supposed insalubrity of irrigation, as exemplified in parts of the existing canals of the Jumna. This question has received at the hands of the committee appointed by government for the special purpose of investigating it an examination so careful and elaborate, that no difficulty can exist in forming an opinion upon it.

For the detailed results on which such an opinion is based, I must refer to the last section of volume second of this work. I need only say here, that it has been clearly and satisfactorily proved that irrigation, *per se*, is not to be dreaded as a cause of sickness. What is to be dreaded, however, is the interference of canal-works with the natural drainage of the country, and the consequent formation of stagnant swamps. It is to this cause chiefly, if I may not say exclusively, that the bad effects traceable on existing canals, constructed in the infancy of our experience, are to be attributed. As elaborate precautions, involving heavy additional expense, are to be observed on the Ganges canal, there seems every reason to believe with the committee that, "on the whole, we may consider ourselves warranted in anticipating on this work a far less amount of contingent evil than has been experienced on the canals of the Jumna, which were originally constructed without reference to many important points, which have especially been kept in view in projecting the present work."

The proposed measures will, I believe, dispose effectually of

the objection to the canal on sanitary grounds, and in removing it will rectify an evil the importance of which I have no desire to under-estimate.

The preceding form the only objections which, to my knowledge, have been advanced against the Ganges canal; and though the Government has already overruled them all, and the great work will be opened in 1853-4, I have still thought it might be useful to show the grounds on which the resolution to prosecute the project was founded. Viewing the details of the system of irrigation between the Ganges and the Sutlej as actually executed, in progress of execution, or projected with a fair prospect of being carried into effect, the results are very important. When all the works are fully developed, the agriculture, on which about twelve millions of souls are dependent, will be secured — produce, which cannot be valued at less that £10,000,000 sterling per annum, will be placed beyond the contingencies of season—and public revenue, amounting to about £3,000,000 yearly, will be permanently protected from fluctuation in ordinary times, and, I might say, from annihilation during extraordinary ones. Our canals of irrigation will probably be the most permanent records of our dominion in the East; for if the lapse of five centuries was insufficient to obliterate the canals of the Mahommedan dynasty, ours are certainly capable of a far more protracted existence. The natural habits, the everyday life, and the old associations of the people in Northern India, all incline them to look favourably on works of irrigation in every form; and government can do nothing more popular among them than to encourage the extension of such works, wherever the means exist for supplying them with water.

SECTION II.—Irrigation between the Rivers Sutlej and Indus.

Before the annexation of the Punjaub to British India in 1849, it can scarcely be said that canals of irrigation existed at all within its boundaries. On the north, and in the interior of the Himmalayan mountains, the streams which flow through the high-lying valleys had, doubtless, been employed for generations with success in producing remarkable examples of local fertility.

The numerous torrents which form the subordinate drainage-lines of the southern face of this great range had also been utilised at various points between the *debouches* of the Sutlej and the Indus. Again, in the extreme south, the inundations of the Indus had long been employed to fill channels of irrigation which rendered useful service to the crops of the hot season and rains, and on the western frontier the same river had furnished limited supplies for the irrigation of small tracts of country on its banks. But that great plain, bounded on the east and west respectively by the two rivers above mentioned, presented no works by which its admirable natural capabilities had been taken advantage of; and the introduction of a general and comprehensive system of irrigation was one of the first objects to which the local government directed its attention on the definitive settlement of the country. Measures were taken to have the different rivers examined, and the tracts of country lying between them duly surveyed. How far these preliminary investigations may have been already carried, I have not at present the means of knowing, but I believe that a great canal from the river Ravee, destined to confer the benefits of irrigation on the region between that river and the Beas—the special country of the pure Seiks—has been duly matured, and, if not in actual progress of execution, will doubtless soon be commenced. It will form the first link of that chain which is destined ultimately to be carried over the entire surface of the kingdom, and the final results of which will unquestionably be to make the Punjaub, in so far as agricultural productiveness is concerned, the Lombardy of the East.

Eastward of the river Jhelum, the country is admirably adapted in topographical structure for purposes of irrigation. It slopes to the southward, from the base of the Himmalaya, with a gentle and efficient rate of fall; its soil, when supplied with water, is capable of producing all the most valuable crops in Indian agriculture: the quantity of water which might be brought into use between the Sutlej and the Jhelum would not fall below from 12,000 to 15,000 cubic feet per second—a volume sufficient for the actual watering of from 2,500,000 to 3,000,000 of acres, and for the effective irrigation of a tract of three times this area.

Westward of the Jhelum, towards the Indus, and in irrigable

localities beyond the latter river, the features of the country are more rugged and unmanageable; but there is no reason to doubt that such difficulties as might present themselves would be overcome.

The time has not yet arrived for giving details of the works which have been projected for the internal improvement of the Punjaub. They are, in fact, in the first stage only of their development; and I have alluded to them thus briefly to show that the subject has engaged serious attention, and is in fair progress. The promise is great. In a memorandum on the question, submitted in 1849 to the Marquess of Dalhousie, I showed from such data as were then available, that between the rivers Beas and Jhelum, a tract containing 13,500,000 acres of cultivated or culturable soil might be brought under the influence of irrigation by means of the rivers traversing it, and at an expense for works of a little more than £500,000 sterling. The results would certainly not be inferior to those to which I have adverted in the previous section, as having been already secured in the region between the Ganges and Jumna. In addition to the benefits to the State from such works, the value of landed property throughout the country would be much raised; culture would be facilitated and extended; and lastly, in the words of the memorandum before alluded to, "looking to the present condition of the Seiks, a people which would seem to have but two national pursuits—arms and agriculture—I am disposed to think that no resource would tend more directly to their permanent pacification than, while depriving them of the power to earn subsistence by the sword, to furnish them abundantly with the means of gaining it by the plough."

SECTION III.—Irrigation in Central India.

The materials for the subsequent sketch of irrigation and its results in Mairwara, one of the wildest districts of central India, have been derived from the printed report of Colonel Dixon of the Bengal Artillery, the officer to whose personal energy, and devotion to the interests of the people placed under his charge, the chief development of the system is due. To have restricted the details to the works of irrigation alone would have been

doing scant justice to the subject, for these are perhaps less interesting, in a professional point of view, than as being the most influential of those material agents to which the conversion of an entire race, from a state little removed from utter barbarism to one of promising and progressive civilisation, is to be traced. Hence it is that a short account of the social condition of the inhabitants of the region under notice, prior to its subjugation by the British in 1820, has been prefixed to that of the irrigation system, so successfully established throughout it. The contrasts between Mairwara in 1820 and in 1850 are such as are rarely presented to view; and I am sure the conclusions they warrant will have their just effect in stimulating the extension of the means by which they have been produced to other localities, where nature is equally bountiful, and man equally necessitous. In the comparatively settled districts between the Ganges and the Jumna, there are no such strikingly marked examples of the regenerating effects of constant and profitable agricultural employment as Mairwara presents; but even there my personal experience would enable me to point out many isolated instances in which the lawless Goojur, closely allied in race and identical in habits with the Mair, had been weaned from his wild life, and bound to the soil by the new interests which gather round the proprietors of land easy to till and sure to reward. It is certain that all these robber races are husbandmen at heart. Bad government cuts the ties that everywhere, but perhaps especially in the East, link men to the land that feeds them, and casts them loose, to be a pest to their neighbours and to themselves. But the good government that, while it gives the means of culture, insures the enjoyment of its results, appeals to those deep-rooted feelings which are never wholly extinct; and with what success, as illustrated in the case at present under notice, let the following abstract, drawn up by Lieut. Yule, tell pleasantly, at once for encouragement and instruction:—

"The territory of Mairwara forms a portion of the Arabala or Aravulli Hills, which extend from the frontier of Goojerat, in a N.N.E. direction, through the middle of Rajpootana, to the neighbourhood of Delhi. Its northern boundary is formed by the isolated British district of Ajmeer, about twenty-five miles

S.W. from the city of that name; whilst it separates the Rajpoot state of Marwar, or Jodhpoor, on the west, from Mewar, or Oodeepoor, on the east; and it is bounded on the south by that part of the hill-chain which belongs to the latter state. The length of Mairwara is about a hundred miles from N.E to S.W. Its breadth, varying with that of the range, is twenty-five or thirty miles at the northern extremity—towards the south much less.

On the north of the tract some approach to a plain is to be found, though even there small ridges of rock and low hills cut up the surface into distinct valleys. But a very short distance to the southward the country is one mass of hills, intersected by small vales. There are no perennial rivers in the country; and as the drainage naturally makes its way to the plains with extreme rapidity, agriculture was entirely dependent on the falling rain for moisture, previous to the introduction of artificial aids to irrigation; and its results were, therefore, most precarious. The soil is peculiarly fertile, bearing, on the same area, from once and a half to twice as much as the adjacent low-lands of Marwar and Mewar.

The Mairs, or people of Mairwara, call their country *Mugra*, a word signifying, in their dialect, hills. They do not appear to be ethnographically a peculiar race, but have derived their descent mainly from fugitives or exiles, who in former times took refuge in these jungly hills. These fugitives were generally Rajpoots, who intermarried with meaner castes. Although the body of the people consider themselves Hindoos, their Hindooism is of the laxest, nor would they be acknowledged by the genuine adherents of the Brahminical faith. They are perfectly regardless of all the forms of ablution, preparation of food, and other set ceremonies; they pay no respect to the chief idols of the Hindoos, though they worship several of their divinities, and celebrate one or two of their principal feasts. Their food is Indian corn and barley bread. Hog's flesh, venison, fish, and fowls they do not eat; but they partake freely of sheep, goats, cows, and buffaloes when they can; nor do they consider spirits interdicted. Their marriages are conducted after the Hindoo fashion; and it is an imperative duty to collect all the clan to celebrate the funeral feast of a deceased relative.

A portion of the people, distinguished as *Mairats*, profess Mahommedanism; but, with the exception of circumcision and the inhumation of the dead, their customs differ in no respect from those of the other Mairs. With these they eat and intermarry, and they use habitually the Hindoo salutation, "Ram, Ram."

The Mairs bear the character of being faithful, kind, and generous, with strong clannish feeling and very considerable courage. They are very reckless of their own life and of that of others, easily excited to desperate acts, and as easily subdued by mildness and patience. The sword was the Mair's constant companion and the arbiter of all injuries. A feud not avenged in one generation was handed down as an heirloom to posterity.

For centuries this people had been notorious for their depredations, and indeed robbery was the profession of the whole race. The peculiar position of their wild strip of hilly country, surrounded by the Rajpoot principalities, enabled them on their thieving raids to dash into the very heart of those states, whilst their native strongholds were always within hail, if danger threatened. On such forays the Mairs were not usually cruel, or fond of needless bloodshed, and their rules prohibited the robbery of Brahmins, women, or professed devotees. Plunder was their object, not war; and, though daring enough, they never attacked soldiers or armed men; but the Rajpoots by no means liked to encounter them at close quarters. For their predatory excursions they never chose a leader. Their preparatory arrangements and intelligence department were excellent; but in the execution all were equal, and all shared alike in the booty. Each district of Mairwara had its assigned field for plunder in the adjoining low-lands. The horsemen, in small parties, haunted the highways, looking out for marriage cavalcades, and pilgrims bound for the shrines of Rajpootana. The footmen devoted their attention mainly to cattle-lifting, though not neglecting favourable opportunities to rifle travellers. When Ajmeer fell into our hands, it was not safe for an unarmed man to be outside the walls after sunset.

To check these incursions, the protective measures of the Rajpoot chiefs and village communities availed little; and the

payment of black-mail, under the appellation of *dal-kumlee* (grain and blanket), was very general. Some villages made over the crop raised from one or more wells; others paid annually a hundredweight of grain for each well on their lands, with two pieces of cotton cloth. Some chiefs compounded by a fixed yearly payment in corn or cash, or by the assignment of a village.

On the other hand, it was the custom of the Mairs, at the spring and autumn festivals of Hoolee and Dussera, to offer a goat and a hare, or some such trifling present, to the low-country lord nearest whom they were located—a semblance of allegiance repaid to the donors by a liberal bestowal of drink. On such trivial offerings various chiefs based their claims to the hill villages, on the reduction of the country.

In consequence of the continual annoyance from these predatory practices of the Mairs, repeated attempts to subjugate them were made by the large states of Rajpootana. These efforts were quite unsuccessful, and their only result was to increase the audacity of the Mairs, by confirming their confidence in the impregnability of their mountain home. Thus, in the very heart of hostile states, without rulers or leaders, did these bold freebooters remain totally unsubdued, and not only did not *pay* a farthing of revenue, but *levied* it, with no sparing hand, from those districts which chose to buy that security which their own government could not guarantee them.

It remained for a small force of British sepoys, conducted with European order and method, to accomplish, with comparatively little loss, what the undisciplined thousands of native powers had attempted in vain.

In 1818, when Ajmeer was first occupied by the British under Ochterlony, attention was directed to the injury and annoyance sustained from the forays of the Mairs; and it became evident that no peace or prosperity could be insured to the district or the neighbouring states in our alliance, till the race should be subjugated.

An expedition for this object, in 1819, though partially successful, did not effect a permanent subjugation. Another became necessary in the end of 1820. The operations were conducted with rapidity and success; fort after fort was captured; and in

three months the whole of Mairwara was completely brought into subjection, and has remained so ever since.

Many of the towns and villages which submitted were given over, as they were claimed, to Mewar and Marwar. These claims rested frequently, as has been noted, on most frivolous pretences; and the thoughtless liberality which conceded them, after we had expended both blood and treasure in subduing the country, was eventually the occasion of a great deal of confusion and difficulty, the evil effects of which even still exist. Mairwara therefore now belongs, in unequal portions, to the British, as an appendage of Ajmeer, to Marwar, and to Mewar. To us belong four local districts, now comprising a hundred and forty-three villages and sixty-three hamlets, eighteen only of which were inhabited on the introduction of our rule. For a hundred and seventy-five years preceding that period, the district of Beawr was wholly uninhabited. It now contains a hundred and sixty-five villages and hamlets in a high state of cultivation and consequent prosperity. Mewar has three districts, including seventy-six villages and thirteen hamlets, richly cultivated, but so densely peopled that the land is insufficient for their support. Marwar has two small districts on the western side of the hills, containing only twenty-one villages and four hamlets, of very limited population and restricted capabilities.

Thus this people, who had never before acknowledged any ruler, found themselves subjected to three separate governments. There was no controlling authority to insure unity of purpose, to direct amelioration, or to watch and soothe the exasperated feelings arising from ancient feuds. Crime increased, and the criminals of one jurisdiction found refuge in another; punishments were arbitrary and severe, frequently extending to life. Revenge naturally followed. Armed banditti were organised, and infested the whole country. Remedial measures were out of the question; nor could success be expected from them whilst such discord prevailed among the ruling powers, even allowing each system of management to be in other respects good.

Matters came to such a crisis that the native governments would have been expelled but for our support; and as we exercised no general interference to insure a milder or more equitable administration, our interposition virtually operated as an instru-

ment of oppression over a people who were at least entitled to our protection, as we had been their first and only conquerors.

Obviously there was but one remedy for this state of things—in the subjection of the whole tract to one officer, with full civil and military authority. But difficulties with the Rajpoot states for some time precluded the application of this remedy; and it was not till 1823-24, that such an arrangement was carried out. Mewar, in 1823, consented to transfer her villages to our charge for ten years, paying £1500 a-year as a contribution to the general civil and military expenses. Next year Jodhpoor made a similar transfer for eight years of the villages in the immediate possession of that government. But the bulk of the Mair villages on the western side unfortunately remained in the hands of the border chiefs, to whom they had been made over, and these have not shared in the improvement and prosperity of the remainder of the hills.

The officer to whom the charge of Mairwara was intrusted, was Captain (afterwards Colonel) H. Hall, C.B., who had previously been charged with the levy and command of a local battalion in the district.

Within six months after the concentration of authority was carried out, the predatory bands, which had been in full mastery of the country, were broken up and suppressed, the passes were again opened, and traffic revived without molestation. Single constables took the place of armed troops for all purposes of police and revenue; and thus, under the guidance of one master hand, a regular government was, for the first time, established throughout Mairwara.

The villages claimed by Marwar and Mewar have continued under British management, on renewed agreements, till the present time. In 1843, indeed, Government had decided on restoring the twenty-one Marwar villages to that state. This drew from Colonel Dixon a strong and urgent remonstrance, pointing out the deplorable evils likely to result from breaking up the unity of management in Mairwara; the despondency expressed by the people themselves at the prospect of being transferred to native authority; and the probability of their relapsing into their old predatory habits, instead of continuing to settle down into a peaceable, industrious, and flourishing pea-

santry. The Government acceded to Colonel Dixon's remonstrance, and the Marwar Raja consented to the continued British management of the twenty-one villages. But seven others, which had been made over to our superintendence only in 1835, were on this occasion re-transferred to the native power. As took place with the other Mair villages, when these came under us, lawless and predatory pursuits had yielded to habits of rural thrift; and during the eleven years that they remained under British management, the revenue had nearly trebled. The result of the re-transfer, however, has justified Colonel Dixon's remonstrance. The character of the villages has deteriorated; a large portion of the land which had been covered with luxuriant cultivation has relapsed into waste; and some of the inhabitants have migrated within our jurisdiction.

For thirteen years Colonel Hall devoted himself to the social amelioration of the Mairs; to the abolition of demoralising and pernicious customs;* to the substitution of honest labour and settled habits of thrift among the people for an uncertain predatory mode of life. Though it was reserved for his successor to develop irrigation works, as a great engine for the improvement of the country and the people, it was Colonel Hall who first tamed the wild race, who substituted law and rule for anarchy and disorder, and so laid the foundation of all subsequent ameliorations.

Prior to the subjugation of the Mairs, the sword was the usual resource for the decision of disputes and the reparation of injuries. When a more peaceable adjudication was resorted to, various kinds of superstitious ordeal were employed. Colonel Hall introduced a system of *punchayut* or jury, elected by the parties for the adjustment of all complaints of wrong, excepting in the higher cases of crime; and this has acted very well.

Until the people were provided with the means of earning their bread legitimately, cattle-lifting was the general crime. For such an offence, without aggravating circumstances, four or six months' confinement has been considered sufficient. More serious crimes, such as murder, manslaughter, highway robbery,

* The sale of women, and female infanticide, were among the customs thus abolished, and so effectually that the former is scarcely ever heard of, and the latter is regarded as a heinous crime by the Mairs themselves.

and offences of that nature, have been visited with greater severity; but death has not been inflicted as a punishment since the pacification of the country in 1824, and only three individuals have been transported beyond sea. The mysterious nature of the latter punishment, to an ignorant inland people, has always caused it to be regarded with more terror than the sentence of death, which all understand.

A peculiar and valuable feature in the police administration of Mairwara has been the practice of compelling offenders to make good the value of stolen property to the owner, and also to provide for the expenses of their own support whilst in jail, as well as to pay their share of the expenses of conviction. This has been practicable under a system of society where every peasant has been more or less a cultivator, and possessed of a share of the lands of his village. "The system," says Colonel Hall, "is efficacious notwithstanding its mildness. Besides being a direct preventive of crime, it has tended materially to soften the character, to remove atrocity, to enlist the feelings of the country, and, consequently, its active support in aid of the police, and to render resistance to capture, even by a single policeman, very rare. In such a country two thousand police would be ineffectual without the aid of the inhabitants; so that their good-will is of primary importance."

In June 1835, Colonel (then Captain) Dixon of the artillery was appointed to succeed Colonel Hall, who, after thirteen years of unremitting exertion in the improvement of the Mairs, had been compelled by impaired health to seek another climate.

It soon became manifest to the new superintendent that *water* was the great desideratum in Mairwara, and that the first step to the establishment of permanent prosperity must be the provision of a stable supply. From the hilly character of the country, what rain fell, unless means were used for its retention, speedily flowed off, leaving the soil only very imperfectly saturated with moisture. The rains, too, are extremely precarious; and bad seasons in this respect are the rule, good the exception. The whole amount in favourable seasons rarely exceeds 22 inches, and it often ranges from 8 to 12. In 1832 no single shower fell, and Mairwara experienced all the miseries of famine. Grain

was to be had in small quantities, but there was a total absence of forage. The cattle perished, and numbers of the people fled to Malwa. Of those who remained, many were driven to seek a livelihood by plunder, for their cattle had been swept away, and they had no longer the means of tilling the soil. Thus the country was partially denuded of inhabitants; improvements received a severe check; and the popular morality was sadly deteriorated. For several years the district did not recover the position which it held before the famine. In ordinary seasons a break of twenty-five or thirty days without a shower often caused, in a degree, the same results. Some villages, again, were destitute of water even for domestic purposes during the hot months; and the inhabitants were thus compelled to seek a residence in some more favoured locality till the recurrence of the rains, when they would return to resume their rural labours. At other places the people had to fetch their supply of water from a distance of two miles. Drought prevailing so frequently, the Mairs were constantly in doubt whether they should not remove to other countries favoured with more auspicious seasons, to earn their bread as labourers. Thus the minds of the people were constantly unsettled; and it would have been futile to look for settled amendment in their morals and habits until effectual arrangements should have been made for preventing their constant migration, and abolishing the inducements to plunder abroad, by providing them with the means of gaining their livelihood through honest industry at home.

Moreover, it was of great consequence that the people should not merely be insured against scarcity of food and forage, but that they should be so closely employed as to have no *leisure* for plundering excursions. Many of the villages had only one harvest, viz., in the autumn (*khureef*), and that entirely dependent, as has been said, on the rain-fall. In a good season the crops would be cut in October and housed by November. The rainy season rarely commences till late in June or early in July. During this long vacation from labour, mischief enough might be concocted to neutralise all measures of moral amelioration. It was therefore of great importance that provision should eventually be made in every village of means for raising both an

autumn and a spring crop (*khureef* and *rubbee*), which would give full occupation throughout the year.

The one thing necessary, then, to bind the inhabitants to the soil, to steady habits, and to British rule, was the supply of water. Small as is the fall of rain, there was every reason to believe that, were arrangements carried out for retaining and applying the whole of its amount, a sufficiency would be obtained for the security of the cultivator.

Colonel Hall, during his administration of Mairwara, had made or re-established seven tank-embankments. The benefit to the people, and the returns of revenue to Government, had been great, whilst the outlay was very trifling. But the plans of Colonel Dixon for the improvement of the country, and indeed their object—the placing the whole district in a position to withstand a season of drought—required a rate of progress and extent of measures with which the previous work would bear no comparison. Such a system could not be carried out without the sanction and the ample aid of Government; but this sanction was accorded, and it became necessary to arrange methodically for the spread of improvement.

The objects aimed at were, 1st—The insuring a sufficient supply of water for the permanent cultivation of the soil; 2d, The subjugation to the plough of tracts then abandoned to jungle; 3d, The conversion of every individual inhabitant into a cultivator, so that no excuse should remain for robbing and cattle-lifting.

The principal means to the attainment of these objects were the formation of large reservoirs of water, by damming up the main water-courses of the country. Such reservoirs (*tulaos* or *tank-embankments*) would supply irrigation to the lands below them through sluices, and to higher levels by the usual rustic machinery, the wheel or bucket; their beds on the withdrawal of the water would afford luxuriant cultivation, requiring neither manure nor further irrigation; and percolation from the tanks would supply numerous wells in rear of the embankment, by means of which land might be brought into cultivation which was much beyond the influence of the sluices. Of the construction of these tanks we shall speak more fully hereafter.

Such great works were necessarily to be executed at the expense of the State.

Minor improvements were to be carried out by the people themselves, assisted, when advisable, by pecuniary advances from Government. These minor works consisted mainly in digging wells, in constructing small tanks (called *narees*), and in raising dry stone terrace-walls across the fields—a measure indispensable in the hilly portions of the tract, both to prevent the soil from being washed away, and to maintain moisture in the land.

At the time when these improvements were taken in hand the people had scarcely recovered from the effects of the famine of 1832. By that visitation their energies had been prostrated, and they had quite given way to despondency, taking up the idea that Providence willed not the prosperity of Mairwara. When urged to sink wells, they invariably replied that the soil was rocky, and that there was no supply of water. It was needful to prove to them by example that exertion only was wanted in order to success. Various wells were commenced in the villages adjoining the battalion * cantonments, at the public expense. A supply of water was duly found, and on completion the wells were given over to the villagers. In this manner about fifty wells were brought into useful employment. The people, thus encouraged, quickly took up the work. Such as desired aid were provided with tools, and an advance equal to twenty shillings in cash. At every village where circumstances were favourable, wells were sunk; and this was the first step taken by the people themselves to throw off their lethargy, and to work out their own independence and welfare. This was a great point gained.

But wells could only be sunk in certain localities, such as the valleys, and near the banks of hollow channels, where there was a reasonable promise of water. The best position was in

* The organisation of this battalion, of which five-eighths of the men were Mairs, was one of the most useful of the means of improvement employed by Colonel Hall. Service in its ranks taught the young men habits of order and obedience, and when they returned to their villages they became influential for good among their friends. The battalion has always behaved with commendable steadiness and propriety in quarters, and with the old gallantry of their race in the field.

rear of an embankment, where there was a certainty of finding springs derived from filtration. Much land again could not be benefited by the great reservoirs on account of its elevation or distance, and could not be improved by well-digging on account of the rockiness of the soil. In such situations *narees* might be constructed. These are miniature tanks formed at the expense of single or associated cultivators. The *naree* consists of an earthen embankment faced with dry stone, thrown across a hollow so as to retain a spread of water varying in different instances from two or three to fifteen or even thirty acres in extent. Indian corn is sown to the rear of the embankment, and the retained water is employed in irrigating this crop during a break in the rains, or in bringing it to maturity after their cessation. On the withdrawal of the water, the tank-bed is sown with barley. One moderate fall of rain fills the pond, and insures both these crops. The construction of these works, varying in expense from £2 to £20, falls within the means of the peasantry; for in all agricultural works the people are assisted by the authorities with advances of cash calculated to meet one-half or one-third of the outlay. Such works require few repairs, and are very remunerative in favourable sites.

In the more hilly ground, where the rapidity of the descent would prevent the construction of any kind of reservoir, dry-stone walls are carried across the small valleys to preserve the soil from being washed away, and at the same time to obstruct the passage of the rain-water, so that it shall be absorbed by the soil. In some instances a series of such dykes is built, commencing from the opening of a gorge, and carried over a distance of one or two miles, ascending one wall above the other to the crest of the hills. Each of these dykes is provided with one or more escape outlets, through which the surplus rain-water flows down into the terrace below; and so from field to field it descends, saturating the soil of each in succession. The dykes also retain the decayed vegetation which is washed down the faces of the hills, and so add to the fertility of the soil. On the first shower of rain falling in June, the terraces are sown with Indian corn, which is ready for cutting on the expiration of two months after the seed has vegetated. On its removal the land is sown with

barley. In this manner two crops (during moderately favourable seasons) are annually raised from these terraced or dyked lands.

The land of some villages towards the south of Mairwara is restricted to small rocky valleys between ranges of rugged hills. Terrace-walls have been thrown across these valleys, and the intervals supplied from the nearest available spot with earth of sufficient depth for the growth of corn.

The rugged precipices on all sides precluded the employment of cattle or carriages, and all this work has been done by hand. In this manner, for example, the peasants of one village (Bursawura) have in twelve years formed forty acres of productive land, at a cost of from £27 to £67 per acre; and so with other villages. Such unexampled industry deserved a substantial recognition. Some of the villages received money-presents equal to five or six years' land-rent, and others were granted a perpetual remission of a portion of their rent.

Besides such improvements as these, applicable to villages already existing, there were within the tract thousands of acres of waste-land, which it was most desirable to reclaim, and which would afford locations for numerous new villages and hamlets. Notice of the intention of bringing these lands under cultivation was made public, and candidates pressed forward as colonists. The *putel* or headman of the new settlement was generally selected from among the younger brothers or sons of the *putels* of adjacent villages, and on him devolved the collection of the tenantry. His relatives and connections, living out of our jurisdiction, usually formed the village community. The village was formally inaugurated, and remissions in rent were granted until the hamlet was considered sufficiently advanced to bear the usual rates. During the first year, one-sixth of the produce was taken as the government share; during the second year one-fifth; and during the next four years one-fourth. After that period the rates were the same as in old villages. At the same time, the settlers were furnished with advances of money for the purchase of bullocks, and for the construction of small works. These advances were repaid in four or six instalments, within three years after the establishment of the village. Tools were furnished free to all who needed them, but the settlers were expected to build

their own houses. Tanks were constructed in suitable situations, and the usual adjuncts of wells, *narees*, and terrace-walls, sprang up. By these new settlements, population received a considerable augmentation, the government revenue was increased, and the haunts of wild beasts were swept away. In the course of twelve years, the whole of the jungle wastes have been converted into fruitful fields, affording food and employment to the inmates of one hundred and six new hamlets.

The superintendent was urgent in his exhortations to the people to look to the soil as their only source of prosperity and independence. They were warned that now, when Government had come forward offering assistance to all, inactivity would not be tolerated; that, as they had every facility of providing for themselves and their families, every man must do so by honest industry, and that any attempt to prey on their neighbours would meet with heavier punishment than even before, and offenders would now not only incur the displeasure of Government, but would be regarded as outcasts by their own families.

The solicitude with which the subject was urged, and the substantial pecuniary aid with which these solicitations were backed, satisfied the people that the advancement of their interests was the honest object of the superintendent. In every village of Mairwara, as in other parts of Central India, there are certain handicraftsmen and others regarded as the hereditary servants of the community, who do not usually engage in tillage, but are remunerated for their services by annual and occasional allowances of grain. All these, however—the smith, carpenter, potter, barber, and leather-dresser (*Buláhee*)—were induced, by judicious persuasion and aid, to take their share of agricultural employment; and even the minstrel, whose hands had never before been blistered by a plough-handle or other vulgar implement of toil, was at last enrolled as a convert to rural industry. From this conversion of the village-servants into husbandmen no inconvenience resulted. Indeed, the measure contributed to an increase of hands, for their brethren and friends in less prosperous circumstances joined them from places beyond our rule.

In projects for reclaiming waste-lands, there were sometimes no candidates for their occupation. The adjacent communities were

then urged to make arrangements for their settlement within a given time, otherwise the superintendent would adopt a plan of his own. The villagers, perhaps, desired the jungle for grazing, or thought we could not establish new hamlets without their assistance. But we were prepared for all contingencies. To bring Mairs of other clans on the lands would have induced feuds. The agricultural castes from the low country, such as Játs, Goojurs, or Mussulmans, would have feared the displeasure of the villagers claiming the location. The plan adopted was to establish a community of the *bulåhees*, or leather-dressers. One of that caste, generally from the village claiming the lands, was named *Putel*, and collected his brethren from the adjacent states. The *bulåhees* were skilful and diligent cultivators; and as they always comported themselves humbly and respectfully before the lords of the soil, the latter made little objection to their settlement. Five *bulåhee* villages have in this manner been settled. It has not been necessary to extend the number, as the threat of adopting this measure has in every other instance sufficed to induce the clan owning the waste to undertake its reclamation, for such a step would argue slackness on their part, and their honour would be touched.

But Colonel Dixon was not contented with employing the engrossing labours of the field as a preventive against idleness and consequent crime; the same medium of industrial reform was applied successfully to convicted offenders. In 1836, a gang of robbers from Marwar having plundered the town of Gungapoor in Mewar, in returning with their booty through British Mairwara, were attacked by the villagers, who, in their new character as cultivators, had suffered from the depredations of the gang. Twelve of the band were slain, and twenty-nine made prisoners. These were confined in the Mairwara jail under sentence for four years; but before the expiration of this period, a plan was suggested for converting these men, whom poverty and ignorance had made robbers, into thrifty and useful subjects. A portion of uncultivated land some miles from the jail at Nya Nuggur was assigned to them. The prisoners were permitted to quit their confinement every morning, partially unfettered, for the purpose of digging wells at the new settlement, returning

every evening unattended to sleep in the jail. On the expiry of their sentence, they were joined by their families and relatives, and commenced in earnest on the cultivation of the soil. A year after their release, the new village exhibited signs of prosperity. It now contains twenty-seven families, and pays a yearly revenue of £77. From the day of their location, no charge of misconduct has been brought against them. The character of the people has been marked by order, propriety, and untiring diligence.

In the autumn of 1836, a report was submitted to Government on the public works which had up to that time been executed, setting forth their benefit to the people and the State, and at the same time soliciting a further outlay on works of irrigation. The application was cheerfully responded to, and it became a custom in the autumn of each year to forward a Tank Embankment Report, and solicit sanction for further expenditure. In the works first selected for execution, the expenditure was trifling when compared with the returns, as it was an object to convince the Government that money so disbursed would not only tend to promote the civilisation and morality of the people, but would be actually returned with ample increase into the treasury. Where the limitation of public outlay restricted the construction of large tanks at our expense, villages anxious to carry out such works on their lands were accommodated with advances. In such cases the usual remission of revenue to new lands was not granted, the full quota being exacted in repayment of the advances.

As the improvements progressed, the eagerness of the peasantry to partake of these benefits became so intense that the authorities were unable to keep pace with their demands for aid. Such villages as had not been taken by the hand were envious of the good fortune of those who were having tanks constructed on their lands. Among others who had not yet shared in the process of improvement was the village of Sooreean. They had importuned aid in constructing a tank; but engagements were already so extensive that their claim was necessarily deferred till next season. This was unpleasant news for the villagers, but they had been prepared for the contingency. A few months afterwards, they requested a visit from the superintendent, without assigning a reason. His camp was accordingly pitched at Sooreean,

and, to the surprise of all, it proved that the people had, of their own accord, and from their own means, constructed a serviceable and substantial embankment. Disappointed of our aid, they had mustered sufficient funds for the purpose by the sale of cattle, and by the betrothal of their daughters. Such devotion at the shrine of improvement merited a mark of special approbation. They received a donation of £40—equal to half the outlay—and were highly satisfied, whilst their example was held up to their countrymen as worthy of imitation.*

The land-rent paid to Government in Mairwara is one-third of the harvest produce in cash, estimated on a valuation survey of the standing crop. Headmen of village communities pay one-fourth only; and certain of the more valuable kinds of produce, such as cotton, opium, sugar-cane, tobacco, and vegetables, are charged at fixed rates, equivalent to from 13s. to 18s. per acre. This system has latterly been extended also to Indian corn, wheat, and barley. In time, it is to be hoped that the people will be prepared to accept a fixed settlement without apprehension. A further step towards it was made in 1847-8, by farming out each village for the season to its own cultivators. The people are not hardly dealt with, and remission is always accorded when there are reasonable grounds for it.

In the construction of all new works, the people, independently of receiving tools and cash advances, enjoy extensive remissions of rent. Thus the land attached to a new well pays only one-sixth of the produce during the first year, one-fifth the second, and one-fourth during the third and fourth. After that the established rates are exacted. Village-tanks partake of remission according to their cost. Such cultivators as preferred it had a portion or the whole of the debt due on cash advances remitted, the improved land at once paying its full share of revenue. In all measures of amendment, the superintendent's study was to make rural toil pleasant and remunerative.

The process of constructing an irrigation tank-embankment is only applicable on ground of irregular surface. A tract which

* A good master makes good servants; hence Colonel Dixon bears the strongest testimony to the efficiency of his native establishment, who aided him with hearty good-will in all his works.

is actually hilly not only affords facilities for such works, but derives peculiar benefit from them, since the rain-water, if not artificially impeded, immediately flows off to the lower lands, without penetrating the soil. Land, however, which is broken merely by gentle undulations, is also adapted for embankment works.

To provide a supply of water, the embankment must of course be thrown across a hollow, containing a water-course, which in the rainy season carries off the drainage of the tract. The extent of surface drained by this water-course is a point of the first consequence, as on this will depend the quantity of water, and of land which the work will be capable of irrigating. For a large work, intended to irrigate one hundred acres and upwards, the area from which the feeder draws its supplies should cover several square miles. In a country where the seasons are so uncertain as in Rajpootana, the supply of water cannot well be too great, provided an ample escape-outlet is left for the superfluity.

The provision of water being satisfactory, the next point to attend to is the position of the embankment. An experienced eye will at once take in the various recommendations of different sites; as in all engineering works, various considerations have to be weighed against one another. A first desideratum obviously is, that the dam should be as short as possible, which indicates a point where the span of the valley is at its narrowest. But it must also be looked to, that the ground which is to form the bed of the tank shall be nearly level; for if it has a rapid descent towards the site of the embankment, evidently the latter must be greatly elevated, in order to give an extended area to the sheet of water. These two conditions may be inconsistent, and require to be compromised. The narrowest span of the valley may probably give an insufficient extent of area for the tank; and it may be necessary to increase the latter, by selecting a site which requires a greater length of embankment.

Other points to be taken into consideration in selecting a site for an embankment are, the relative level and position of land to be irrigated, the quality of soil for foundations, and the proximity of stone and lime, and of water, for the supply of the works when in progress.

Briefly, the indications most favourable to the construction of a tank-embankment may be thus enumerated:—1st, A channel bringing down an ample supply of water; 2d, For the bed of the tank, a broad expanse of nearly level land in front of the embankment, having a slight dip towards the latter; 3d, That the land to the rear be of greater extent than the bed, and slightly lower in its level, in order that every portion of it may be irrigated through masonry sluices constructed in the embankment, and communicating with earthen drains, leading to each field; 4th, A rocky foundation at little depth from the surface; 5th, That water be procurable from the bed of the water-course, or from a well, for the use of the work and workpeople; 6th, That stone, lime, and fuel be within reasonable distance.

It will rarely happen that all these advantages are offered at one locality. The main object of the tank, it is to be recollected, is the irrigation of the land to its rear. A careful survey of the proposed site should be made, including the levels of the intended dam, and of the land to its front and rear. The elevation of the embankment, and the area of the bed to be submerged, may then be adjusted and determined, and an opinion as to the irrigative powers of the tank, in reference to its depth and expanse, may be formed. The expense of the work is then to be contrasted with the probable return from the irrigation of the land in rear, from the growth of luxuriant crops in the bed after the withdrawal ofthe water, and from the more indirect benefit arising from the multiplication of wells supplied by filtration from the tank.

Amongst the hills, the selection of a site for a tank is much less difficult than in the comparatively plain country. In the former localities, cultivation in the bed of the tank is generally out of the question, and consequently it is not an object that the bed should have great expanse. Depth of water is the chief recommendation, with facilities for carrying it by sluices and drains to the cultivation in rear. Small openings and gorges are found in abundance, only requiring the construction of a barrier-wall to close the water-course, when a tank is at once formed.

There are five varieties of tank-works in Mairwara and Ajmeer.

1st, The cheapest and most simple is that which consists solely of an earthen embankment. It can only be formed when the soil is tenacious and the country level, affording a wide spread of water, not exceeding three or four feet in depth. The bank towards the front should present a long slope, and be planted with grass or shrubs, to protect it from the action of the water. The only expense, in addition to the earth-work, is the provision of a few masonry sluices. There are but few and small works of this nature in the country, for they are not adapted to its general hilly character.

2d, An earthen bank, with a front of dry-stone. The greater portion of the smaller works raised by the cultivators are of this character. To add to the strength of an embankment, it is provided with a dry-stone wall to the rear as well as to the front, the intermediate space being filled with earth well beaten down. Sluices and outfalls, for surplus water, must be provided of lime masonry. Dry-stone walls, having a breadth of one and a half or two yards at the base, may be carried to a height of twelve feet. It would be imprudent to carry them higher, unless they are strengthened by a sloping bank of earth towards the bed of the tank.

3d, An embankment similar to that just noticed, but having a simple front-wall of lime masonry. Such works are common in the more level parts of the Ajmeer district, where the embankments are necessarily of great length, many of them exceeding three thousand yards. Had the soil been tenacious, an earthen dam would have sufficed; but as it is extremely saline, and deficient in adhesiveness, masonry retaining-walls have been necessary to protect the earth-work. Many of the smaller works in Mairwara are constructed in the same manner. A rear retaining-wall of dry-stone or lime masonry is added in the vicinity of the water-course. Such works, when once the earth is well settled, require little repair.

4th, The most important kind of embankment, and that which is employed for the obstruction of the larger water-courses, consists of a massive front-wall of lime masonry, buttressed at intervals by solid bastions of the same material, which give strength to the fabric, and break the force of the waves. Behind

this wall is a broad earthen bank, which is secured again in rear, through the whole or a part of its length, by a retaining-wall of dry-stone or lime masonry. Where the rear height of the embankment is great, a second and sometimes a third such wall is carried longitudinally through the earth-work. The work is provided with sluices, according to the amount of irrigation to be derived from it. Finally, there must be an escape or outfall, sufficiently extensive to carry off a body of surplus water equal to the maximum discharge of the stream, before its course was obstructed. Some of the most beautiful mountain-lakes of Mairwara owe their existence to dams constructed after this fashion.

The embankment-wall, in the works described by Colonel Dixon, appears to be generally raised four feet above the sill of the escape-outlet.

All the embankments are planted on the exterior slope with trees, which add much to the beauty of the works, whilst they serve to bind the soil. They should, however, be kept well to the rear, lest the roots should penetrate and injure the masonry in front.

The trace of the embankments is generally a straight line, but sometimes it follows two or more lines, meeting in angles, according to local circumstances. In one instance, of which a plan is given by Colonel Dixon, a convex form in plan is given to the embankment. This economised masonry in the particular case, the ground which would have been the position of a straight embankment being several feet lower than that attained by following the curve. The foundation, too, was better, and a greater obstructive mass was presented to the waters. This dam (Gohana) presents a satisfactory instance of the facility with which such works are constructed in a hilly region. The opening left by nature for the passage of the water does not exceed sixty yards. By closing this narrow gap with a strong barrier of masonry and earth, a beautiful lake has been formed, securing two hundred and fifty acres of cultivation, giving food and occupation to fifty-nine families, and amply repaying the State's outlay.

In the larger works, where the wall was raised to a great elevation, very large stones were used in the foundations and waterface, some of them requiring the power of forty men to move

them. The sluices through the embankment are protected towards the lake by hollow bastions, pierced with apertures for the admission of the water, and provided internally with spiral staircases, for the convenient removal of the sluice-plugs. Channels of masonry are conducted through the embankment to the rear, where the water is received in small cubical cisterns. These cisterns are pierced with apertures at different elevations, communicating with the various irrigation drains for the distribution of the water.

The escape-outlet generally consists of a massive masonry weir, having its lower side sloped off. The flood-water, as soon as it reaches the height of the sill of the escape, passes off in a cascade over the slope.

In these large tanks, when the fall of rain is considerable, much water remains over until the ensuing year. In such a case, the bed remains unsown, but the extent of cultivation in rear of the embankment is proportionally increased. In seasons of drought, luxuriant crops are raised in the beds of the tanks. Thus, whether the rain be moderately light or very heavy, provision is made for one crop or the other. In the former case, the greatest return is from the autumn harvest; in the latter case, the autumn crops are rotted by excessive wet, whilst the produce of the spring crop is proportionally increased.

5th, One other kind of reservoir remains to be noticed. This is formed by a great weir, or wall of masonry, without earthwork or flood-escape. Such works are extensively used in the more hilly parts of the district, where the valley to be closed does not exceed a hundred yards in breadth. Any excess of water runs over the crest of the wall, which is sloped off on the lower side. When the height is considerable, it is well to raise the work in successive portions year by year, allowing the floods to pass over it. When the masonry has thus been allowed to set well, no apprehension need afterwards be entertained. Such works, when of good material, rarely require repair.

Numerous weirs similar in construction, but of smaller size, have been carried across the natural water-courses below the large tank-embankments, in order to economise the wastage by filtration. In constructing such works, care must be taken to

continue both ends of the weir some distance within the banks of the hollow, to prevent the flanks being turned by the stream. By a series of such works a continuous canal, as it were, is maintained from tank to tank along the hollows, serving to supply numerous wells beside its banks. In this manner, by means of a system of tanks connected by successive weirs, a sheet of cultivation, of varying breadth, has been carried, in one instance, for an unbroken distance of twenty-six miles. A few years ago this was a jungle waste, with the exception of a few patches of well-cultivation. A similar course is pursued with each separate valley. A strong weir is constructed at the head of the valley to maintain a body of water, and to break the force of the torrent. In its rear, at convenient intervals, stone dykes are thrown across the breadth of the hollow, and when any subsidiary water-course joins the valley, its supply is stopped by a second weir. In this manner, by means of a few substantial weirs, intermixed with stone fences built across its breadth, the valley is converted into a series of terraces of rich cultivation, ascending to the summit of the hills.

The following Table (No. I.) exhibits the principal dimensions of the masonry in some of the Mairwara tank-embankments and weirs, which have been described by Colonel Dixon in detail, with the spread of water, the area deriving fertility from the work, and the total cost of each in a round sum converted into English money :—

TABLE No. I.

Name.	Length of embankment wall, or weir.	Breadth.		Depth of foundation.	Height above foundation.	Spread of water.	Area irrigated, including cultivation in bed.	Cost.
		In foundation.	At upper surface.					
	Feet.					Acres.	Acres.	
Kabra, . . .	620	27	10	9	24	182	204	£625
Juwaja, (Escape Weir added to ancient embankment), . .	251½	28	..	6	16	218	364	378
Roopana Weir, . .	522	10½	3¼	0	18	25	36	220
Kalee Kuncur, . .	3369	42	6	0 to 10	28	182	437	1655
Gohana, . . .	460	25	4¼	10	28	94	250	427
Burar Weir, upper, .	240	30	7	8	36	72	109	400
Do. do. lower, .	343	12½	6½	10	20	72	29	256
Loosanee, . . .	575	29	..	20	24	218	273	810
Cheela Bura, . .	954	5	3½	6	14	36	83	not stated
Dewatan, . . .	1333	21	..	19	16	145	328	

The next Table (No. II.) exhibits the result of some of the works which have been detailed above on the capabilities of the villages benefiting by them, as shown in the increase of the number of the families, ploughs, wells, and village tanks belonging to each community, and in the amount of its revenue paid to Government during eleven years preceding the preparation of Colonel Dixon's Report, (1835-6 to 1846-7).

TABLE NO. II.

Name of village.	Increase in number				Increase in revenue.
	of families.	of ploughs.	of wells.	of village tanks.	
Kabra, .	From 38 to 133	22 to 100	3 to 46	0 to 31	£47 to £206
Juwaja, .	... 25 to 122	17 to 100	8 to 28	0 to 15	25 to 179
Kalee Kunkur,	... 0 to 118	0 to 110	0 to 25	0 to 14	0 to 109
Burar, .	... 70 to 440	64 to 329	131 to 301	...	385 to 885

From year to year these irrigation works were carried on as the sanction of Government was accorded. During twelve years of steady application to their development, the extent of the work done and the benefit conferred far exceeded the anticipations of the most sanguine at the time when general and systematic improvement was first contemplated.

The next Table (No. III.) will show, in abstract, the whole number of tank-embankments constructed in Mairwara up to the date of the Report, with the total spread of water and area of cultivation dependent on the works.

TABLE NO. III.

DISTRICTS.	Number of embankments and weirs.	Spread of water in bed.	Area irrigated, including cultivation in bed.
		Acres.	Acres.
Ajmeer Mairwara, .	158	6323	10,557
Mewar Mairwara, .	120	3077	3,960
Marwar Mairwara, .	12	275	309
Total, .	290	9675	14,826

This abstract does not include twenty-three weirs on the water-courses of the Beawr district, all of which contribute to the spread of cultivation.

Two of the largest tanks (Dilwara having a spread of 364 acres, and Kalingur of 437) were embanked many years ago; but they were not turned to account for agricultural purposes till after the conquest of the tract in 1820–21. A third tank, Surgong, is a natural reservoir, which has been converted to profitable use within the last few years.

Seven of the embankments were made, or repaired, by Colonel Hall. The remainder have been constructed under the direction of Colonel Dixon.

The following Table (No. IV.) exhibits the result of these improvements on the agricultural appliances, on the estimated population, and on the Government revenue of the whole of Mairwara.

TABLE No. IV.

	Wells.	Ploughs.	Village tanks.	Estimated population.	Revenue.
Total in 1835-36	2233	2712	—	39,648	£9,680
Total in 1846-47	6148	9691	2065	100,282	21,022
Positive increase,	3915	6979	2065	60,634	£11,342
Ratio of past to present,	1 to 2.753	1 to 3.753	—	1 to 2.529	1 to 2.171

The two subsequent Tables require no comment.

TABLE No. V.

Table No. V.

Statement showing the Total Government Land Revenue of the Three Divisions of Mairwara from 1835-36 to 1846-47, and the Aggregate Increase in these Years.

Mairwara.	1835-36.	1836-37.	1837-38.	1838-39.	1839-40.	1840-41.	1841-42.	1842-43.	1843-44.	1844-45.	1845-46.	1846-47.	Aggregate increase.
	£	£	£	£	£	£	£	£	£	£	£	£	£
Ajmeer, .	3,529	4,798	5,174	6,358	7,000	7,847	7,894	5,756	9,118	7,662	8,201	10,101	41,089
Mewar, .	5,430	6,643	6,698	7,208	6,489	6,915	6,312	3,884	7,943	8,165	9,496	10,016	20,039
Marwar, .	721	1,002	1,148	1,178	1,174	1,326	1,197	807	688	778	723	904	2,994
Total,	9,680	12,443	13,020	14,744	14,663	16,088	15,403	10,447	17,749	17,605	18,420	21,021	64,122

Table No. VI.

Statement of Sums expended in Mairwara, under the sanction of Government, for Tank Embankments, from 1835-36 to 1845-46.

Mairwara.	1835-36.	1836-37.	1837-38.	1838-39.	1839-40.	1840-41.	1841-42.	1842-43.	1843-44.	1844-45.	1845-46.	Total.
	£	£	£	£	£	£	£	£	£	£	£	£
Ajmeer, .	993	1,012	1,116	613	774	871	1,918	2,132	2,375	2,457	2,325	16,586
Mewar, .	—	300	400	300	400	300	750	606	758	695	1,268	5,775
Marwar, .	—	—	300	180	120	50	470	250	—	180	200	1,750
Total,	993	1,312	1,816	1,093	1,294	1,221	3,138	2,988	3,131	3,332	3,793	24,111

The promotion of civilisation in Mairwara embraced other projects besides direct aids to agriculture. Colonel Dixon soon saw that a town was much wanted in the district. Excepting those attached to the regimental bazaar, there was scarcely a merchant or trader of any description who had been found willing to settle in Mairwara. A few, residing in the neighbouring Rajpoot towns, monopolised the dealings of the Mair peasantry, to their infinite disadvantage. An open market, where produce might command an equitable return, was therefore greatly needed. Capital, too, was much wanted. Any means by which the cultivators could obtain small advances of cash, on fair terms, would inspirit the people, and accelerate all plans of amendment. The successful settlement of a town and bazaar would supply these wants.

We cannot follow Colonel Dixon's interesting details on this subject further than to state, that in 1836 the town of Nya Nuggur (New City) was founded, and prospered beyond all expectation. Traders and mechanics flocked to occupy the solid and handsome shops; neighbouring villages got rid of their mud hovels to imitate the substantial architecture of the capital; rival bazaars sprang up in other parts of the country, evidencing the increase of produce and growth of wealth; confidence was imparted to all sections of society.

In 1838 a noble rampart-wall was carried round the town two miles in circuit. The population at the date of the report consisted of 1955 families, of every caste and profession, and the average annual value of the merchandise which had been imported, exported, or passed through the city in the three preceding years, amounted to £147,191.

Before the building of Nya Nuggur, the number of carts kept by the people of the whole *purgunna*, or local district, was forty. There are now 680. They find employment in carrying materials for building to the towns, villages, and public works; in conveying goods and merchandise to the neighbouring marts; in carting manure and agricultural produce, and in the carriage of the people on marriage festivities. A profitable trade, too, is driven in the transport of small spars from the southern hills to Ajmeer, Nusseerabad, and more distant towns.

Another object which occurred to Colonel Dixon as desirable, was to have some recurring occasion of general reunion, where all the clans might meet, converse freely, and each detail the progress of improvement in his own village. By such free and general intercourse, the state of each place would become known, —some would be encouraged, and others stimulated. It was accordingly determined to have an annual fair at Nya Nuggur, to which all should be invited to come, bringing their wives and children in their best apparel. The fair-day was fixed in the beginning of autumn, when the whole country is covered with the rain-crop, the tanks overflowing with water, and agricultural prosperity in its zenith.

The invitation was cheerfully responded to. The fair was numerously attended by the people, decked out in their best attire, and attended by their minstrels. Clans, kept apart by the feuds of ages, met on one neutral spot, and greeted each other. Opportunity for useful comparisons was afforded.

The fair is maintained regularly, and is attended by 8000 or 10,000 Mairs, as well as by Rajpoots and others from the adjoining provinces.

The scope and success of Colonel Dixon's measures have been sufficiently indicated in the preceding pages. Though much was done by his predecessor for the civilisation of the Mairs, yet undoubtedly all this was most precarious whilst their subsistence and employment were dependent on most uncertain seasons; and the development of a great system of irrigation works (by which the fallen rain is economised to the utmost, and distributed in time and place of need, instead of sweeping down the valleys and passing away in a useless torrent) has been the means of giving permanence and advancement to the improvement in the character and habits of the people.

By these works the country has been fortified against the miseries of famine; tracts of wild jungle have been converted into fruitful fields, dotted with villages, and alive with rural industry; population and revenue have more than doubled; families, which for generations had abandoned their native hills, have returned to seek their traditional landmarks; the inducements to constant migration and unsettled habits done away, and a

taste acquired for the sweets of profitable toil. The wild unmastered caterans of 1820 are thus found to have become in 1848 a thrifty, thriving, peaceful, and industrious peasantry, an example to their neighbours, whose terror they once were.

The rapid strides of improvement among the Mairs were not unheeded by the neighbouring authorities. The Ajmeer chiefs began to find that their tenants were leaving them, attracted by the benefits enjoyed in Mairwara, and appealed for relief to the superintendent of their district. He addressed his brother-officer in Mairwara, pointing out that the terms offered by him were so unusually favourable, that a large number of cultivators would be enticed from the district, and the tenants would be unable to pay their rents. The Mairwara superintendent's reply indicated the true source of these migrations, as lying in no invitations from him or reduction of assessment. The peasantry, indeed, were aided to purchase cattle, to sink wells, and accomplish other field improvements ; and the authorities were further advancing their interests by raising tank-embankments to secure water for the extension of cultivation. The chiefs of Ajmeer, it was suggested, had only to do likewise, and, with their strong advantage in the ties which bound the peasantry to their natural lords and native soil, they could not fail to retain their tenants. If they would follow the example set in Mairwara, in freely conversing with their people, hearing their grievances, relieving their wants, and aiding them, either by pecuniary advances or by provision of water, prosperity would certainly result. The energies of the chiefs were roused ; they saw that the choice of retaining or losing their peasants lay with themselves. Commencing on some small embankments, they found their profit, and extended the system of improvement. Each year contributed to the increase of agricultural means. Thus in twelve years the estates of Mussooda and Khurwa have been enriched by ninety tanks. The peasantry who had come over to Mairwara returned to till their ancestral lands, and, since systematic improvement began, no single cultivator has quitted his village. The new spirit spread widely through the adjoining districts. The estates of Mewar also shared in the benefits of the good example. In Marwar the desires of the chiefs prompted them to follow, but fears of their court's avarice forbade.

In the end of 1840, which had been a very inauspicious season, no rain having fallen till September, Colonel Sutherland made a tour of the Ajmeer district, and the distress of the people forced itself on his attention. There were few tanks, and wells enough only to provide a few acres of barley, scarcely sufficient to feed the bullocks, to say nothing of food for the people and government dues. Even the rain which fell abundantly in September was lost for the spring harvest, there being no means of husbanding the water. For several years before, the revenue had been in a state of progressive decline. It was urged that this was owing to unfavourable seasons. Yet in Mairwara, under the same experience of seasons, the revenue was steadily increasing. In the one district, life, energy, and progress were the characteristics; in the other, poverty, inaction, and discontent.

Colonel Sutherland desired that the means which had been so beneficial to Mairwara should be applied to the redemption of Ajmeer, and he resolved to commence at once, without awaiting the sanction of Government. Colonel Dixon was ordered to proceed into the district, and to report on the local facilities for tank-embankment in the village lands held immediately of Government in Ajmeer. Promptly a report was drawn up, embracing the construction and repair of thirty works, estimated to cost £5550. Orders were given for immediate commencement, and thus the first step was taken. The old course was followed,—every village visited,—its means and capacities discussed personally with the inhabitants,—sites for embankments or wells examined,—assistance tendered to all,—and, above all, the health, content, and respectability which would result from adherence to thrift, inculcated on their minds. With the example of Mairwara before their eyes, the people entered readily into Colonel Dixon's plans. Embankments rose, wells were sunk, *narees* were constructed, barren land became fertile, new villages were located; in a word, Ajmeer threw off her lethargy, and the villages were pervaded by energy and life.

The works constructed in the Ajmeer district do not essentially differ from those of Mairwara, though some of the dams are necessarily much more extensive, on account of the comparatively level country in which they are situated.

The effect of the new works has not been so striking in Ajmeer

as in Mairwara, in its results either on the productiveness of the country or on the government revenue.

In the first place, the soil is naturally much less fertile. Much land in Ajmeer is so impregnated with salts that no crop can be raised. Thus it frequently happens that the bed of a tank is quite unfit for sowing, and also that, from the prevalence of salt in the adjoining soil, land enough is not available in rear of the tank for the consumption of half the water retained by the embankment.*

Another cause which has prevented the government revenue from benefiting by the irrigation works as in Mairwara, is the large extent of land, of the best quality, in Ajmeer which has been alienated for the endowment of religious institutions, &c., or (according to a peculiar Central-Indian custom) for the maintenance of guards for the protection of the villagers' property, and of travellers and merchandise traversing their boundaries. From such estates a low water-rent is the benefit reaped by Government. Many freehold and leasehold estates, too, are interspersed among the government villages in Ajmeer. These derive great aid from our tanks, through percolation, without making any return. It was not so in Mairwara, where there was no diversity of interests, and all improvements bore fruit directly in an enhanced revenue.

Due attention was given in Ajmeer also to the reclamation of waste land. The number of new hamlets located during the few years preceding the date of the report was thirty. One object which guided the selection of sites for such locations, was the prevention of highway robbery; for experience teaches that there is no surer manner of providing for the security of roads.

The following Table (No. VII.) exhibits the length and height of three of the Ajmeer tank-embankments, described in detail by Colonel Dixon, with the cost in sterling money, the spread of water, and the área of land cultivated from each:—

* Land of this description can only be rendered fit for culture by a large admixture of sweet sand. Trees are thus useful in retaining the sand which sweeps over the country during the hot winds; and as trees spread over the face of the district, the soil will be beneficially affected.

TABLE—(No. VII.)

Name.	Length.	Height.	Spread of Water.	Area of Cultivation.	Cost.
	Feet.	Feet.	Acres.	Acres.	
Lohurwara, ...	7955	14	280	160	£774
Durathoo, ...	3106	22 and 30	400	280	2599
Sreenuggur (Old and New), ...	1720	12 and 26	120	180	1465

The total number of tanks constructed on the Ajmeer lands, holding directly of the Government, is as follows :—

No.	Total Spread of Water.	Total Area of Cultivation.
	Acres	Acres
112	13,086	9794

Three of these are ancient works; the remainder have sprung up under Colonel Dixon's superintendence. But besides these, 489 tank-embankments of various sizes have, under the influence of his example, been constructed by the landholders possessing, rent free and on leasehold, estates in the district, assisted by temporary advances of public money.

Up to 1841, the rates of revenue levied in Ajmeer were heavy, amounting to one-half the produce from the cultivators, and to two-fifths from head-men, Brahmins, and some other classes. At the period referred to, the rates were reduced to two-fifths from the cultivator, and one-third from the privileged classes. This reduction, coupled with the aids to agriculture in the form of irrigation works, stimulated the people to exertion, and, in spite of untoward visitations of locusts, frost, and blight, the results on the revenue have proved very satisfactory, as is shown in the appended statement :—

REVENUE OF AJMEER.

1842-43.	1843-44.	1844-45.	1845-46.	1846-47.	Aggregate Increase.
£30,706	£37,764	£37,806	£38,500	£40,531	£31,777

The sums expended on tank-embankments in the government villages are as follows :—

1841-42.	1842-43.	1843-44.	1844-45.	1845-46.	1846-47.	Total.
£6,869	£3,837	£4,486	£6,560	£6,622	£9,271	£37,645

Whilst the authorities were occupied with the construction of these works, the people in the district were not idle. The returns show that the government villages of Ajmeer have received between 1841 and 1847 an addition to their former means of 1254 new wells, and 375 *narees*, or irrigation ponds."

To the abstract of the results of irrigation in Central India thus presented, I have myself but a few words to add. From the statistical tables it appears that, in Mairwara alone, the revenue of the state has advanced from £9680 in 1835-36, to £21,021 in 1846-47, or upwards of 216 per cent. Now, the proportion of the gross produce of the soil which constitutes the land-rent may be approximately assumed at one-third. Hence, the agricultural produce of the district has increased in value from £29,040 in 1835-36 to £63,063 in 1846-7. While the State, accordingly, has obtained, during the twelve years included between the dates above noticed, an aggregate increase of revenue, as shown in Table V., of £64,122, the Mairs themselves have benefited to the extent of double this sum, or £128,244; being upwards of £10,000 per annum added to the wealth of the community, as the reward of their newly-acquired habits of honest industry. The means by which these ends have been attained have cost, in execution, a total sum of £24,111, expended by the Government, on which it has already received, from the enhanced land-rent only, the almost incredible return of 265 per cent! Nor has this result been attained by adding to the burdens of the people; for Mairwara, in 1847, flourishing, fertile, and endowed with the permanent machinery of irrigation, actually pays less in proportion to its population than in 1835. In the latter year the population was estimated at 39,648, and the land-rent was £9680, being 4s. 10½d. for each

soul. In 1847 the population had increased to 100,282, and the land-rent to £21,021 per annum, giving a rate of 4s. 2d. over all, or about one-seventh less than it was before the measures of amelioration on the large scale had begun to influence the resources of the district. Viewed simply in a financial point of view, therefore, the results exceed even the most sanguine expectations. On the moral effects no comment is necessary; every right-feeling man will best estimate these for himself.

Though the comparatively unfavourable circumstances of Ajmeer have limited the effects of the irrigation system, yet even there its influence has been very marked. Within the five years between 1842-43 and 1846-47, the government revenue has advanced from £30,706 to £40,531 per annum, giving an aggregate increase during that period of £31,777, or about 84 per cent on the sum expended by the State for the requisite works, which amounts to £37,645.

Owing to the nature of the land tenures and the number of rent-free estates, the government revenue does not enable us to indicate the full extent of the pecuniary benefit to the agricultural community, but, estimating it very moderately, it cannot at present be less than from £25,000 to £30,000 per annum.

There is only one point more to which, before concluding, I would wish to advert. With all the increase of irrigated area to which the system established by Colonel Dixon has led, placed thus before us, it is natural to inquire, what have been the results on the sanitary condition of the country? Have the means of introducing plenty at all impaired the vital energies on which its full enjoyment by the people is dependent? This question has undergone a careful and minute investigation. The Report of the Medical Committee on canal irrigation is accompanied by two Appendices marked I. and K., wherein are given the results of examinations conducted personally by Doctors Weir and Collyer, the medical officers, respectively in charge of the districts of Ajmeer and Mairwara. The method of examination was the same as that adopted in the canal districts of Northern India. Enlargement of the spleen, as found in a given number of children and adults, was the test for the comparative intensity of miasmatous influence. This test was applied to a sufficient

number of localities throughout the two districts, to authorise a fair inference as to their sanitary state in general, and I am happy to be able to add, with results of the most satisfactory character. In Mairwara, where irrigation has been so largely extended, out of 175 children examined, three only were found to have enlarged spleens; and of 237 adults of all castes and classes, there were but twelve in the same condition. Of the five degrees of the test scale, the two higher, which indicate intensity of disease, are *blank:* the medium degree includes only *one* case, the ordinary ten, and the small four, making a total of fifteen out of 412 individuals, taken indiscriminately from among the inhabitants of twelve of the most highly irrigated villages in the district. In such regions as Mairwara, there is always a certain prevalence of fever, after the close of the rainy season, due to natural causes, which can easily be understood. The proportion of enlarged spleens in the highly irrigated villages of Mairwara, indicates a sanitary state equal to the entirely unirrigated districts in Northern India. Hence the conclusion arrived at by Dr Collyer, that hitherto irrigation has produced no deleterious effects whatever on the health of the people, may safely be accepted as correct.

From Table No. III. it appears that, in Mairwara, 14,826 acres have been brought under the direct influence of irrigation—that is to say, actually watered each year from tanks only—excluding the increase from wells, which is not specified, but which cannot be less than from 20,000 to 25,000 acres, as upwards of 3900 of these works have been added since 1835-6, each of which would, I presume, be sufficient for the watering of from five to six acres at least. In Ajmeer, the area of tank-irrigation amounts only to 9794 acres, and the well-irrigation is proportionally limited; yet the sanitary condition of the irrigated portions of the latter district is inferior to that of the former. Mere extent of irrigation, therefore, cannot be the cause of such difference, and there must be local sources of disease independent of the use of water in agriculture. What these may be Dr Kier does not specially indicate in his Report, but he refers to the season preceding that during which his investigations were made, as having been generally an unhealthy one over the entire district; and to this possibly the larger proportion of spleen disease may be attributed. Of 280 children

examined personally by Dr Kier, in fourteen separate villages, forty-seven were found to have enlargement of the spleen; and of the same number of adults of all classes, forty-three were in the like condition. In Mairwara we had about 1-27th of the total number examined, showing in their persons the proofs of past disease, while in Ajmeer this ratio rises to between one-sixth and one-seventh. To interpret correctly these facts would require an amount of local information not now at command, and the only inference I feel warranted in drawing from them is, that it is possible to employ irrigation extensively, as in Mairwara, without producing any bad effects on the general health, provided always the same conditions are maintained. The chief of these conditions appears to be perfectly unimpeded drainage. In Mairwara this is produced by the natural features of the country, but there are very few localities in which the same end could not be obtained by judicious artificial means. A light absorbent soil also characterises this tract, as it does those in Northern India, where irrigation has been found innocuous.

While, however, Ajmeer, relatively to Mairwara, exhibits an inferior sanitary state, it is far superior to the tracts irrigated from the canals in Northern India, and is equal to some, though not to the most salubrious, of the high-lying and wholly unirrigated districts between the Ganges and the Sutlej. Of the ninety cases of spleen disease recorded, no less than sixty-eight belong to the lowest degree of the test scale—that is, the enlargement was discernible, but small. The sweeping of an epidemic fever, such as that before referred to, over the entire district, might easily leave such indications of its effects as the above; and I would be unwilling, without further proof, to attribute these to the influence of irrigation. Of the remaining twenty-two cases, seventeen were ordinary and five medium, the two higher degrees of the scale being blank. Dr Kier's own views are clearly and decidedly expressed. "To form a judgment," he says, "as to the health of the inhabitants from their looks and appearance, there was the best evidence everywhere that they were far from being an unhealthy race. Indeed, in few of the villages visited could I make out any considerable amount of disease." The general healthiness is attributed to

the same circumstances as in Mairwara—an absorbent soil, perfectly free drainage, and the position of the villages themselves on high, dry spots. To the latter point, perhaps, too much importance is attached both by Drs Collyer and Kier; for when it is borne in mind that the whole working life of the cultivators of irrigated districts is spent in the fields themselves, it is tolerably certain that, if malarious influence is developed, the mere position of the habitations will not protect them much from its effects. If the vitiated atmosphere has to be inhaled all day, and every day, the mischief will be done in spite of the favourable circumstances of the dwelling-places. To be able to sleep, however, beyond the influence of noxious exhalations, would doubtless be beneficial in some degree. In the tracts under notice, however, I am disposed to think the evidence proves that irrigation, as practised there, generates no malaria to avoid, and that to this fact the healthiness of the cultivators is attributable.

I have to apologise for the length to which this Appendix has extended. I have been carried on by the interest of the subject; for it is the rare charm of such works as I have been describing, that those engaged in them can see with their own eyes, and feel, in their own pleasant experience, the physical and moral results their labours have produced. We are all, accordingly, somewhat prone to become enthusiasts, and to draw, perhaps, too largely on the sympathies of others less personally interested than ourselves. But I will still hope that the details given of the inner machinery, and the visible results of one of the most important and most extensively applicable of the agencies for good to the State and the People which we possess in India, may be held of sufficient interest to justify the length at which they have been dwelt upon.

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